An Investigation into Summary Data of Solved North American Serial Killer Cases to Identify Trends within Murder and Disposal Locations and Time Between Estimated Death and Recovery

By

Cody Raymer

A thesis submitted in fulfilment of the requirements for the degree of

Master of Forensic Science (Professional Practice)

in

The School of Veterinary and Life Sciences

Murdoch University

Dr. David Keatley

Mr. Brendan Chapman

Semester 1, 2019

Declaration

I declare that this thesis does not contain any material submitted previously for the award of any other degree or diploma at any university or other tertiary institution. Furthermore, to the best of my knowledge, it does not contain any material previously published or written by another individual, except where due reference has been made in the text. Finally, I declare that all reported experimentations performed in this research were carried out by myself, except that any contribution by others, with whom I have worked is explicitly acknowledged.

Signed: Cody Raymer

Acknowledgements

I would like to thank both Dr. David Keatley and Mr. Brendan Chapman for their ongoing support and guidance throughout the completion of my Master's degree and thesis. The knowledge and expertise they have provided throughout this course will always be appreciated.

I would also like to give thanks to my mum and Paige Luckhurst for always finding time out of their own lives to listen to and provide feedback on my work, and for their ongoing encouragement and support. Lastly, the overwhelming support from the academics and my family and friends has been greatly appreciated throughout all of my studies.

Table of Contents

Part One

Literature Review

An Investigation into Summary Data of Solved North American Serial Killer Cases to Identify Trends within Murder and Disposal Locations and Time Between Estimated Death and Recovery

An Investigation into Summary Data of Solved North American Serial Killer Cases to Identify Trends within Murder and Disposal Locations and Time Between Estimated Death and Recovery

By

Cody Raymer

A literature review submitted as part of the requirements for the unit

BIO612

Master of Forensic Science (Professional Practice)

in

The School of Veterinary and Life Sciences

Murdoch University

Supervisors:

Brendan Chapman (Murdoch University)

Dr David Keatley (Murdoch University)

Semester 1, 2019

ABSTRACT

Homicide investigations require significant resources and personnel from multiple departments, therefore, it is critical to be thorough and explore all lines of enquiry to ensure that these cases do not turn cold. Many factors have been identified that are associated with increased solvability. These include, efficient use of the first 48-hours, body disposal locations, forensic awareness of the offender and decomposition rates. The aim of this review was to explore the extent at which these factors affect solvability and their resulting forensic and criminological implications, regarding time frames and methods for evidence collection, ability to apprehend and link offenders by understanding the types of killers they are through forensic awareness strategies. In the absence of these cases being solved, this review also addresses the major discrepancies noted within the structure of cold case reviews. The literature ultimately determined that further research into body disposal location, particularly, bodies disposed of in water vs. non-water environments and discovery of body since estimated time of death (within 48 hours or over 48 hours) is required. This will be carried out by investigating 54 North American serial murderers and 125 of their respective victims, active between 1920 to 2016, to identify if there are any statistically significant trends between the aforementioned variables, when broken down into indoor and outdoor cases and 8 specified time series.

TABLE OF CONTENTS

List of Abbreviations

CAM – child abduction murder

CSI – crime scene investigation

PMSI – post-mortem submersion interval

PMI – post-mortem interval

ADS – aquatic decomposition score

ADD – accumulated degree days

TBS – total body score

KADD – Kelvin accumulated degree days

MO – modus operandi

CDI – cadaver decomposition island

PPE – personal protective equipment

1. INTRODUCTION

When conducting a homicide investigation, it is crucial to be thorough and explore all avenues of enquiry to prevent them from becoming cold cases (1). Within homicide investigations, there are many criminological and forensic factors that have shown to substantially influence solvability, including victim-offender relationship, marital status of offender, distance between incident site and body recovery location, time taken to locate the body and availability of resources within police departments (2-4). In law enforcement training, there has been particular emphasis on the "first 48 hours", as research has indicated that this time period has a major impact on homicide clearance rates (2,5). These 48 hours have significant forensic and investigative implications if they are not utilised efficiently (2). Many studies have indicated the implications outside of this period to be; evidence degradation and finding leads and apprehending offenders, due to loss of information and vital evidence, particularly in incidences where a body has not yet been located (6,7). In addition, specific studies conducted on child abduction murders have emphasised that these children are generally always murdered within 3 hours of the abduction, often referred to as the 'golden hour', placing a significant emphasis on the actions taken in these investigations within these 48 hours (2,8).

Locating the body of a victim is a major factor in homicide investigations as it may often be the only physical evidence pertaining to the case and many prosecutors will not go to trial without a body (2). In addition, without identifying the body and disposal site, there are limitations for evidence collection and, even if located, these evidence sites may have succumbed to tampering or contamination (2,10).

Tampering may arise from different sources including: animal or scavenging activity or the potential of an offender returning to the scene to interfere with the scene or body (11). Contamination may occur between; personnel and evidence, between evidence types, or between evidence of different crime scenes (11). With advancements in forensic science, particularly, the increase in DNA kit sensitivity, with the ability to detect as low as 100 pg of DNA, it is empirical to reduce the risk of contamination as it may ultimately result in inadmissibility in court and lead to a miscarriage of justice (11,12). First responders and personnel at scenes can reduce contamination by ensuring PPE is worn and gloves are changed between exhibits, ensuring exhibits are packaged and transported separately by different personnel and maintaining a chain of custody (11). This is why evidence collection, storage and transport is crucial in investigations to ensure admissibility in court (11).

There are also forensic implications surrounding the location in which a body has been disposed of, including rate of decomposition and the resulting consequences it may have on evidence collection (10). Research has indicated that temperature and moisture are major contributors to the biochemical processes of decomposition (10). Bodies that have been exposed to conditions that accelerate decomposition will hinder evidence collection and important post-mortem details, such a wound analysis and time of death estimation, which may aid investigators in indicating foul play has occurred, or linking similar cases (2,10).

Despite efforts of law enforcement and investigators, there is still a significant decline in homicide clearance rates and thus an increase in cold cases (1,2). There is also an apparent lack of research that explicitly investigates body disposal location, particularly bodies disposed of in water vs. non-water environments and discovery of the body since

estimated time of death (within 48 hours or over 48 hours) and the surrounding forensic and criminological implications.

2. SOLVABILITY FACTORS

Significant research has been conducted in the area of solvability factors that influence both active and cold case investigations. Main findings of these studies have indicated that crucial factors include: time taken until body discovery, specifically whether they are found within 48-hours; body disposal location; forensic awareness of the offender; and decomposition rates and factors that affect these (2,10,13-23).

2.1. 48 -Hour Period

The significance of the "48-hour" period in investigations has been discussed within the literature and emphasised in TV shows such as *The First 48,* following investigators in the first 48 hours of homicide investigations, indicating that solvability significantly decreases outside of this time frame (13,14). The implications outside of this period include the inability to apprehend offenders, linking cases and degradation of evidence, due to exposure to the elements, where water and UV both have degradative effects on DNA (11).

The importance of locating victims within 48-hours is specifically vital in child abduction cases. Brown and Keppel (15) conducted a study on the effects of time and distance separation as solvability factors in child abduction murders (CAM) indicating that time is crucial for solving child abduction murders. Their research indicated that as high as 74-76% of cases resulted in children being murdered in less than 3 hours of abduction, and 42% of children were already murdered before reported missing (15). This was also supported by Walton and Pettem (16), identifying that there is an issue with the mandated

24 h period for missing persons to be reported, as children are generally murdered within 3 hours of abduction. Also noted in the Brown and Keppel (15) study was a failure in linking cases where bodies had been transported and disposed of across different jurisdictions in 36% of cases. It is apparent however, that this area of CAM has been severely understudied, particularly with reference to solvability factors. This is of concern, due to the apparent critical time periods associated with CAM, therefore it is strongly advocated that further research is carried out for time as solvability factors in not only CAM, but homicides in general to provide a greater understanding and ultimately guide investigators in these investigations.

Case clearance has also shown to be influenced by the 48-hour period, where successful location of victims and apprehension of offenders within this period, increases the rate of clearance. Carter (17) and Sewell (18) studies on respectively homicide process mapping and the stress of homicide investigations have indicated that successful convictions increase with proper utilisation of law enforcement training within the first 48-hours. The concept of the 48-hour period is supported by Canadian clearance rates, indicating that approximately half of solved homicides are resultant in suspects being apprehended within the first 48 hours, and up to 70% within the first week (19). Supporting this, Pastia et al. (20) stated that over 70% of cases they investigated, were cleared within the first 48-hours and deduced that the longer a case went uncleared, it was more likely to remain so, thus emphasising the importance of clearance within the first 48-hours.

In contrast, research has indicated that cases that take longer to solve are generally due to a number of reasons including: carrying out crimes across multiple jurisdictions, drug related crimes, crimes involving guns (over knives or beating deaths), cases where a body

has not been located and offenders adapting their M.O to avoid detection (13,21-23). Consequently, these factors result in the delay and or inability to secure a scene and collect evidence before degradation or contamination occurs (23).

2.2. Body Disposal Location

The location in which a body has been disposed of may provide insight into the type of individual who committed the offence. It may indicate whether the individual was an organised or disorganised killer (24-26). For example, research has indicated that impulsive, disorganised, unstable and violent offenders are prone to leaving the body at the crime scene, and thus are less likely to avoid detection by making errors at the scene, leaving incriminating evidence behind (24-26). Supporting this, other studies have indicated that organised killers often move their victims from the initial crime scene to avoid detection, typically have more forensic awareness and will utilise this knowledge to prevent leaving evidence at the scene (25-27).

Supporting the notion of body disposal locations as solvability factors, research has generally concluded that homicides occurring indoors, specifically inside homes, are more readily solved than those occurring outdoors (28-31). This is owing to the ability for evidence to be better preserved, with protection from the elements, such as rain or extreme heat which may alter or degrade evidence, such as DNA (31,32). By contrast, body disposal locations occurring outdoors may indicate forensic awareness of the offender by attempting to avoid detection (22-24). Outdoor locations are more readily exposed to the elements, which may degrade or inhibit the collection of evidence (22-24). Other examples of forensic awareness strategies include: moving bodies from the original crime scene to an outdoor

location, creating multiple scenes and potential for interference with scavengers or extreme weather conditions thus delaying detection and apprehension of the offender (11,22-24). This research indicates the importance of identifying the body disposal location, and knowledge of the associating criminological and forensic implications with these locations in aiding investigators in their approach to homicide investigations.

2.3. Forensic Awareness

Historically, in the 1970s, the only reference for information on how to avoid detection after committing a crime were fictional crime novels (11). However, now there is sufficient literature and readily available information on forensic science and avoidance methods (1,11). Offenders are now more forensically aware, and crimes are becoming more difficult to solve, reflected in the decline in homicide clearance rates (1,11). Utilising methods that will either prevent or delay the discovery of evidence, crime scenes, or recovery of a body are often adopted by offenders in homicide investigations (2). This concept is known as forensic awareness and refers to an offender's knowledge of forensic evidence and the adaptation of their M.O to take precautions, such as destroying evidence, moving a body from the original location, or utilising PPE to avoid apprehension (33,34). However, there is a current gap in the literature on the extent of application of forensic awareness strategies by offenders at scenes (23,27,35,36). Beauregard and Field (27) indicated that moving a victim's body after a murder is done so as an avoidance strategy, delaying time until recovery and thus associative evidence. However, this study was not able to explain the extent that moving a body results in delay of recovery, which would be recommended for further research. Beauregard and Bouchard (35) deduced that offenders

that exhibit target selection and break into residences to undertake specific sexual acts are both more likely to exhibit forensic awareness, however, this study was only conducted on sexual assault cases, so precaution should be taken into applying this knowledge to non-sexually motivated homicides. Conclusively, although forensic awareness is becoming more common, they found that the understanding and application is inconsistent, with many offenders neglecting to destroy evidence, rather being more concerned about protecting their identity (35).

The current literature explains that forensic awareness is becoming more common and readily applied by offenders to avoid detection. However, there are other criminological theories that are lesser known, such as geographical profiling and routine activities theories, that can help provide insight into not only the location but also the type of criminal an offender may be, supporting the notion for interdisciplinary collaborations in solving homicides (37-40).

2.3.1. Supporting Criminological Theories

Geographical profiling is used as a guide for determining the approximate location, spatial pattern of crimes and potential characteristics of an offender (37). This is done so by mapping the locations of each offense, to determine the likely area in which an offender resides (37). In addition, depending on the location of these offenses, details about the offender, such as if they are opportunistic or planned may be established (37). For example, if an offense is generally committed within close range to the area where an offender resides, it may indicate they plan out their attack, by selecting victims close by (37). The application of this in criminal investigations, may aid investigators in narrowing down the

focus of their investigation, with support from forensic evidence, or in the absence of, to provide another perspective (37).

Similar to the concepts described in geographical profiling, the routine activities theory, originally proposed by Cohen and Felson (40), describes 3 main elements that influence the possibility of a crime occurring based on daily routines of the offenders. These include: a motivated and potential offender, an attractive and suitable target and ineffective or absent capable guardian to protect against violation (40). In the absence of any of these elements, it is assumed that risk of crime decreases (40). In addition, it can also provide information about the type of offender based on their victim selection criteria, where vulnerability is a crucial element for accessing their targets (39). However, a limitation of the routine activities theory is that it is only able to explain the environmental opportunities of the offender-victim relationship, rather than the underlying reasoning as to why offenders are more likely to commit homicides over other individuals, given there is a vulnerable target and opportunistic environment (39). Therefore, they propose a combination of routine activities and social learning theories to overcome this limitation and provide the most understanding into how and why offenders commit these crimes (39).

The understanding of these combined concepts therefore strongly advocates the requirement for interdisciplinary approaches to investigating homicides. This is particularly useful with the increase in forensic awareness amongst offenders, and the lack of, or delay in recovering evidence.

2.3.2. CSI Effect

Due to the popularity of crime shows such as: CSI and Law & Order, the general public have been influenced in the way that forensic science, particularly use of DNA, is portrayed in criminal investigations (41). This can consequently negatively impact real life investigations due to the belief held by jurors portrayed by these shows, that DNA evidence is pivotal to a trial, and without it, they tend to be more unwilling to convict (41). This phenomenon is known as the CSI effect (42-44). This additionally impacts the public's perception of law enforcement, as if they hold the belief that DNA evidence solves crimes and there is none collected at a scene to be presented in court, this may create a strained relationship with police (41). The two main factors that contribute to this issue is the expectation of more or better forensic techniques in trial, combined with the false expectation that forensic science is infallible, consequently impacting jurors' decisions to put more weight onto forensic evidence when presented with it in court (44-48).

Research has been carried out into the presentation of DNA evidence in popular crime TV shows and its resulting impact on jurors. Rhineberger-Dunn et al. (41) conducted a study investigating the presentation of DNA in four popular crime shows (CSI (Las Vegas), Law & Order: SVU, Criminal Minds, and Without a Trace), and whether it supports the CSI effect. The results concluded that 75% of the studied CSI episodes referred to DNA, compared to only 32% of Criminal Minds episodes, supporting the hypothesis that FBI based TV programs are less inclined to discuss forensic evidence in the context of solving crimes (41). However, they are more likely to imply that investigative methods are able to solve cases without the use of forensic and DNA technologies (41). By contrast, TV programs, such as CSI, portray forensic evidence, in combination with police as the ultimate authority for

solving cases (41). However, less than 50% of cases in all 4 dramas were solved with DNA evidence, and those that had DNA evidence available, were cleared at significantly higher rates, ranging from 80% and above (41). This is detrimental as these statistics exaggerate clearance rates in actual criminal cases, where statistics are reported as low as 48.1% of violent crimes being cleared through arrest or exceptional means (41). Conclusively, by over or understating the significance of DNA in court in these TV dramas, the impact of the CSI effect may be furthered. This will result in either an over-reliance or ignorance of DNA evidence in cases, which may ultimately result in a miscarriage of justice (41-48).

In addition, other studies were conducted on a range of audiences from Californian voters, dismissed jurors and undergraduate and graduate students, to determine whether forensic dramas such as CSI and Cold Case influence their perception of forensic evidence and ultimately their decision in court (44-51). The main findings from these studies indicated that in 7 of the 8 studies, these TV programs influenced the audience's perception of forensic science, and in 3 of the 8 studies, also resulted in an impact on their trial decision (44-51). Although not all of these studies resulted in a direct impact on trial decisions, it does indicate that there is potential for influence in real trials. Therefore, informative programs portraying accurate use of forensic science in investigations, including: correct methods for storage, collection and preservation of evidence, accurate time frames for lab processing, fallibility in testing, including potential for contamination and tampering both within the scene, among personnel and within the lab, are required to combat the CSI effect (44-51).

Another factor requiring consideration in these types of dramas that have an effect on degradation and interpretation of evidence and crime scenes is decomposition rates. If a body has been exposed to factors that accelerate decomposition, interpretation of the

estimated time of death, wound analysis and potential for identifying foul play has occurred, significantly decreases (2,10). This therefore, ultimately impacts a homicide investigation and can result in miscarriages of justices if not interpreted correctly.

2.4. Decomposition Rates

Heavily discussed within the literature is how decomposition rates vary in diverse environments including: indoor, outdoor and water locations, and their effects on interpretation of the post-mortem interval (PMI) (52). The PMI is the estimated time elapsed since death, which is particularly important when dealing with homicide investigations (52). Decomposition is a process that occurs in five different stages: fresh, bloated, active decay, advanced decay and dry/skeletal (52). The fresh stage involves the digestion of enzymes, otherwise known as autolysis, which affects are usually visible within 7 days, including; marbling of the skin, skin slippage and post-mortem blister formation (52). As autolysis reaches its final stages, the endemic bacteria will proliferate, releasing gas and odours into the body during putrefaction (52). Additionally, onset of algor, livor and rigor mortis are associated with the fresh stage of decomposition. These are respectively, the cooling of the body, pooling of blood from gravity, and stiffening of the muscles (53).

In the bloated stage, the gasses produced from putrefaction result in the bloating of the abdomen and rise in internal temperature, causing pressure to build, and the consequent release of fluid from the body's orifices (53). This loss of fluids is a part of the active decay stage, which is denoted by loss of body mass due to fluid purging and maggot activity (52). These fluids form a cadaver decomposition island (CDI), and is characterised by strong odours (52). Advanced decay begins as maggots begin to move away from the body

to pupate, and rate of decomposition therefore reduces due to the lack of available material to feed on and thus the drop off of insect activity (52). Last, is the dry (or skeletal) stage, during which any remaining moist skin or tissue forms to the bone, creating a leathery-like texture (52). In addition, there may be increased plant growth surrounding the body due to available nutrients in the soil (52). However, complete skeletonization is not always reached, as it relies heavily on the influence of environmental factors (52).

Evidently, caution must be taken when interpreting decomposition rates as many environmental factors are known to either accelerate or delay the onset of these stages and thus the estimation of the PMI (52,53). These factors include: temperature, insect activity, submersion in water, humidity, and body weight (52,53).

2.4.1. Temperature

Research has been carried out into the effects of temperature on PMI estimation. Cockle and Bell (58) developed a study to validate Vass's universal formula for estimating PMI, incorporating level of decomposition, humidity and temperature, for accurately estimating PMI in bodies discovered outside, on, or under the surface, on a global scale. This study utilised a total of 96 cases located on the surface, and 22 buried in a clandestine grave, with known PMIs (58). Level of decomposition was determined from the photographs taken on day of discovery at the scene. The stages of decomposition were described as 0 (no changes), 3-5 (putrefaction), and 6-8 (liquefaction, soft tissue removal, skeletonization) (58). In addition, ADD was calculated for each case using the Megyesi et al. (55) method.

A subset of 42 of the original 96 outdoor cases were selected based on the Vass criteria. The results generally indicated that bodies exposed to warm temperatures overestimated PMI by approximately 7 times greater (58). By comparison the 6 cases exposed to colder climates, were underestimated approximately half of the actual time since death (58). This would indicate that this model, is not in fact universal and variation exists within different regions (58). Therefore, a consideration of individual models for different geographical regions may be necessary for accurate PMI estimation. Conclusively, their study indicated that increased error was associated with increased PMI, where outdoor cases generally decomposed faster than burial cases, supporting the notion that higher temperatures facilitate decomposition, and therefore, the importance of temperature in PMI estimation (58). Ritchie (59) also supports the notion of higher temperatures accelerating decomposition. This study utilised 6 bodies exposed to temperatures between -6 °C and 35°C, regulated through heating and air conditioning, in a constructed room (59). However, this is a small sample size, so precaution should be taken into its application to a larger demographic and therefore, further studies with a larger sample size should be carried out.

The current literature is inconclusive about the association of cold temperatures with deceleration of decomposition (60-62). Komar (60) noted that in 20 cases involving exposure to cold temperatures that there was a large portion of scavenging activity, therefore, it was undetermined if there was any association of freezing temperatures and decomposition or if tissue loss was simply due to scavenging activity. Micozzi (61) proposed that freezing temperatures will slow down endogenous gut flora and thus delay decomposition, resulting in recolonization of aerobic bacteria on the body from external sources. This was supported by Cockle (62) in their study where bodies were exposed to -

11°C also noted no visible sign of tissue change by autolysis or putrefaction. Conclusively, the extent of cold temperatures in varied temperature ranges, in combination with all factors associated with decomposition has not been explored, thus providing little to no support for universal models, as variation has been observed within the same geographical regions (60-62).

2.4.2. Insect Activity

Studies have indicated that insect activity has a significant role in decomposition. A study conducted by Anderson (63) supports the theory that insect activity accelerates decomposition. Results from their study indicated that between the 3 indoor and 3 outdoor cases, those exposed to outdoor settings were rapidly colonised by a larger range of species, when compared to indoor cases (63). A 5-day delay difference between outdoor and indoor case colonisation was noted with an absence of some species, which may be due to inaccessibility (63). Comparatively, outside carcasses were skeletonised faster with more insects (63). However, it is important to note that this study was conducted on pig carcasses (*Sus scrofa* L.) as a substitute for human cadavers. Keough et al. (64) have determined that precaution should be taken when using pig carcasses as analogues to humans, as their results displayed significant differences between TBS scoring, cautioning that an amended scoring system should be utilised for application to humans.

To further support the theory that decomposition is accelerated by insect activity, is a study conducted by Schroeder et al. (65). This study found that the presence of insects, including larder beetles, accelerated decomposition to skeletonization in an indoor setting controlled at 25°C (65). However, it is important to note that this study was only based on

one human corpse, therefore, future studies with larger sample sizes are required to further validate this research.

Other literature has examined the impact of temperature on insect activity. Ceciliason et al. (66) also notes discrepancies with using the Megyesi et al. (55) model when insect activity occurs. This study deduced that seasonal differences will substantially influence TBS, particularly in summer with the presence of insects (66). This study utilised a total of 140 indoor cases, meeting the criteria of: adults, without being submerged, burned, traumatic injuries or scavenged remains (66). They utilised a modified version of the TBS method developed by Megyesi et al. (55), where 0 is no change, and full skeletonization is 32, for each anatomical region (head, neck, trunk, limbs) (66). Also noted was presence of insect activity, desiccation or mummification, however, the effect of these on PMI estimation was not elaborated (66). Conclusively, this study did not support the concept of a universal model for PMI estimation. Large variance was noted between their 68 cases and the indoor cases utilised, particularly those exposed to insect activity, where large masses between 4-5 kg of blowfly larvae were located on the remains, resulting in massive tissue loss and partial skeletonization (66). Overall, if this was incorrectly misinterpreted, it may result in an overestimation of the PMI. Based on the current literature it is evident that insect activity and desiccation consideration are required for PMI estimation models, in addition to other major contributing factors such as scavenging activity, humidity, air exposure, pH etc, for different geographic regions (66). In the absence of these, there will continue to be large variation in either over or underestimation of PMI's.

2.4.3. Submersion in Water

There is an apparent lack of literature surrounding the effects of decomposition in water. Van Daalen et al. (54) studied the impact of differences between terrestrial and aquatic decomposition through estimation of the post-mortem submersion interval (PMSI). The authors aimed to develop aquatic decomposition scoring methods for achieving standardised methods of decomposition in bodies recovered from aquatic environments (54). The model used was an adaptation of those created by Megyesi et al. (55) and Galloway et al. (56), utilising stage descriptions exclusive to aquatic decomposition phenomena. Anatomical regions were divided into face, neck, trunk and extremities ranging from 1 (no visible change) to 6 (skeletonization) (56). These resulted in facial, body and limb aquatic decomposition scores (ADS), where the sum of these equated to the quantitative stage of decomposition for the whole body (54).

This experiment involved 12 volunteers from varied professions to observe 45 photographs of aquatic decomposed anatomical regions (15 of each – head, trunk, limbs) and score each region (54). This study did not note a TADS of 18 or above, i.e., complete skeletonization, indicating that this could be due to dispersed or sunken body parts in water, and the inability to determine the extent of submersion and resulting effects (54). This could indicate that there may be discrepancies in basing the scoring method on photographs rather than on physical observations. Results determined that TADS was able to predict PMSI, however, noted that a larger sample size should be utilised with more photographs (54). In addition, it is recommended that time and temperature be incorporated into this model as they have major effects on decomposition (54). Additional consideration for body drifting, change in seawater temperatures between depths and distances to coast line,

effects of floating vs. full submersion, clothing, and how air and water decomposition differ may also increase the accuracy of this model (54).

In an attempt to validate the ADS model proposed by van Daalen et al. (54), Reijnen et al. (57) conducted a study with adaptations for bodies recovered in fresh water, to investigate whether there is any correlation between ADS and PMSI, and whether ADS can accurately estimate PMSI in bodies recovered from fresh water (57). The study was conducted on 76 human remains found in outdoor fresh water locations. Results deduced that there was a strong correlation between ADS and accumulative degree days (ADD) of bodies recovered in fresh water, supporting van Daalen et al. (54) model for salt water (54,57). These results indicated that the discrepancies between these bodies of water are not significant enough to warrant an amended model for fresh water, therefore, concluding that ADS is able to predict ADD from bodies recovered from fresh and salt water (54). However, due to the limited research into this specific model and the effects of bodies disposed of in water, further studies incorporating bodies recovered from a range of water locations including creeks, rivers, bayou's, oceans etc, would be required to broaden this significant gap of knowledge.

2.4.4. Humidity

Another known factor that impacts decomposition is humidity. Cockle and Bell (58) noted that humidity has an effect on autolysis and putrefaction, and that decreased moisture often results in mummification and preservation of tissues (58). High temperatures and low humidity are often seen in outdoor settings in states like Arizona, however, mummification in Canada is more often seen in indoor locations with controlled settings

(56,62). Higher humidity resulted in a 3-time delay in reaching the final stage of decomposition in Canada vs. Arizona (56,62). Thus, concluding from the two varied ecozones in Canada (one with higher humidity and varied temperature extremes and other with lower humidity and more temperate climates), support for variation in decomposition between different geographic regions and lack of support for a universal model is evident (56,58,62).

2.4.5. Body Weight

The importance of body weight as a factor of decomposition has been discussed within the literature. Roberts et al. (67) conducted a study on *The Effect of Body Mass on Outdoor Adult Human Decomposition.* This study utilised the TBS method with thresholds for early decomposition being set at 6 and above, advanced decomposition at 19 and above and skeletonization at 27 and above (55,67). This study utilised 12 pigs, with a larger proportion of males, ranging between 73-159 kg (67). Kelvin accumulated degree days (KADD) measured the thermal energy required for the cases to reach each TBS threshold. It was noted that larger body masses resulted in slightly different decomposition patterns, due to the larger amount of adipose tissue liquefaction, and higher amounts of adipocere formation (67). However, body mass only explained 24% of variation in outdoor soft adult tissue decay, and no statistical difference was noted between body mass and decomposition rate (67). It is important to note that this was only a small sample size with a small weight range, and ruling body mass out as a factor affecting decomposition based on this study alone could be premature. Therefore, further studies on a larger scale need to be conducted to validate this research. This notion is somewhat supported by Mann et al. (68), deducing that body size had little effect on decomposition, however; noted that bodies over 110 kg

decomposed faster than those less than 65 kg, in some outdoor cases in Tennessee. This may be due a number of factors, including temperature, potential insect activity or rapid liquefaction of body fats (67,68).

In contrast, findings from an entomological study, found that larger bodies decompose faster than smaller bodies, due to presence of insect activity and the associated raised body temperature (69). However, it is important to note that this study only had a weight range between 8.4 to 15.1 kg, and therefore, is not directly applicable to human cases (69). Additionally, it is unclear whether body mass itself was the main contributing factor for increased decomposition, or if temperature and insect activity played a larger role.

Other studies have indicated that decomposition rate is altered by increased body mass (70,71). Zhou and Byard (70) suggest that body fat alters decomposition via the insulating properties of adipose tissue, decreasing rate of algor mortis, and thus providing more energy for putrefaction in the early stages of decomposition. Campobasso et al. (71) however, suggest that decomposition is advanced via the higher liquid content within adipose tissues, thus promoting bacterial activity and ultimately accelerating decomposition. But when comparing obese to non-obese individuals, noted there may be little or no difference in liquid content, therefore, the difference may be due to other factors, such as the temperature increase associated with increased body mass, or other factors that are known to influence decomposition (70,71). Therefore, more comprehensive studies need to be carried out to provide a better understanding of factors that affect decomposition (70,71).

Other studies have attributed the effect of body mass on decomposition to be minimal (72,73). One study divided pig carcasses into 4 categories ranging from 1 to 50 kg, where those less than 20 kg decomposed faster in the first 6 days, and at day 11, minimal change was evident (72). By contrast, another study conducted on 24 pig carcasses, ranging from 5 to 70 kg concluded that body mass had a major effect on TBS (73). Matuszewski et al. (73) noted that larger bodies decomposed faster during early decomposition and reversed after 100 ADD. These discrepancies within seemingly similar body weight ranges have resulted in opposite effects, which then may indicate that other factors had a larger contribution to the deceleration and acceleration of decomposition, such as: temperature, insect activity etc, but without further studies conducted on human cadavers, with larger weight ranges, it would appear the impact of body mass remains inconclusive.

Although there is significant research conducted into decomposition rates under different environmental conditions, there are still discrepancies seen within the literature about the reliability of: temperature, insect activity, submersion in water, humidity, and body weight on decomposition rates. It is apparent that temperature and insect activity appear to have a significant role in decomposition and thus determination of the PMI. However, further research is required to be conducted into this area to aid investigators in the different types of homicides scenarios they will encounter, particularly within different geographical regions. Specifically, further research is required for bodies that have been submerged in water. Knowledge of factors that accelerate decomposition is critical for interpretation of the estimated time of death, wound analysis and potential for identifying foul play has occurred (2,10). This knowledge can aid investigators to ensure correct interpretation is applied at a scene to prevent inadmissibility in court, the loss of or degradation of evidence, and the potential for cases to turn cold (2,10).

3. COLD CASE REVIEWS

Studies have indicated that there is no universal definition for when a case turns cold. Allsop (1) defines a cold case as when all lines of enquiry have been explored and there are no further investigative opportunities. Other jurisdictions in the USA set a cut off of 36 months, whereas, others define cases unsolved as when there is no evidence to identify, arrest and charge a perpetrator (1,16,74). Therefore, there has been a requirement for distribution of funding, personnel and formation of cold case units to accommodate this (1,16,74-76).

However, research has indicated that there is a gap of knowledge surrounding the effectiveness of cold case reviews and the resources invested into them (75). It is also apparent from the literature, that there is a lack of standardised procedures when conducting cold case investigations, including: reasons for re-opening cases, what factors drive solvability, the general process of cold case reviews, more specifically, the similarities and discrepancies within and between the USA and UK (1,16,74-76).

3.1. Reasoning for re-opening Cases

There has been sufficient research about the reasoning behind re-opening cold cases, particularly in the USA and UK. These range from: justice for victims and families, preventing re-offending, media or family inquiries, or as a part of agency protocol (1,16,74-76). However, the most common reasons appear to be forensic advancements, specifically the use of DNA, new witness testimony, or changes in allegiances (1,16,74-76). These respectively come with their own strengths and weaknesses, which has been discussed within the literature.

3.1.1. Forensic Science

Allsop (75) discussed the motive for utilising resources in cold case investigations. They identified 4 core principal reasons, one of which was advancements in forensic science. This included DNA and fingerprinting and the respective expansion of their associated databases (75). This study concluded the minor costs involved in upkeeping historic samples were justified, as studies have noted it can be easier to obtain a conviction based on historic cases, compared to current cases (1,16,74-76). Operation Advance and Operation Stealth are examples of the successful use of DNA in cold cases (75). These were carried out with funding from the Home Office to respectively review stranger rapes and homicides on a national scale, with proven success, therefore, encouraging forces to engage in forensic reviews. The success of these operations inevitably demonstrated the importance, and value of DNA in unresolved crimes (75).

Multiple other studies conducted into cold case homicide review structures in both the USA and UK, share similar reasonings for re-opening cases (1,16,76). Allsop (1) also mentioned the use of forensic advancements as a progression tool. However, the use of forensic advancements was predominately seen in agencies with established systematic investigative policies in place, i.e., cold case units (1). The lack of standardised procedures and cold case teams on an international scale was another issue identified throughout many studies. The absence of these procedures and specialised units may ultimately affect the efficiency and effectiveness of cold case reviews (1). Walton and Pettem (16) identified that cases were re-opened based on identification through DNA methods, but it was not established whether or not this was the main driver of cold cases. The use of DNA as a

progression tool was also discussed by Atkin and Roach (76) but warranted that it should be used as a tool to enhance detective skills, rather than replace them.

It was apparent from the literature that another major issue in the re-opening of cases was the lack of funding or the redistribution of it to active cases, and inaccessibility of forensic databases (1,16,76). The use of forensic science as a progression tool is heavily consistent within the literature. However, there have been issues identified in factors that affect the storage, collection and preservation of evidence at the scene, and during transport, that may ultimately inhibit their use in criminal cases (75). These factors include: lack of PPE, contamination from incorrect storage or collection methods, cross-contamination between exhibits kept in the same storage bags, degradation of samples, and the cost of testing, which is particularly difficult in the USA, as DNA testing is expensive, and accessibility is limited (11,75).

In addition, the lack of foresight of previous investigators for future advancements in forensic science has resulted in minimal usable evidence for re-testing (75). Therefore, it is empirical to ensure that the evidence available is upkept, to prevent degradation or contamination and thus, inadmissibility in court. Furthermore, when conducting tests, discussion about the order from least to most destructive should be carried out among forensic experts to ensure the sample being used is optimised (11).

3.1.2. Witness Statements

Historically, the USA tended to focus the re-opening of cases on witness testimony (75). Allsop (75) explained that the USA used to focus on changes in allegiances over time, or the coming forward of either new witnesses with information, or old witnesses with new

information. From the literature it would appear this is due to the previous difficulties associated with the backlog of cases and difficulty in accessing forensic labs (75). However, the literature states that the USA and UK now follow similar structures, in that they both rely on forensic advancements for cold cases to progress, and unlikely will not be revisited in the absence of it (75,76). This supports the general conclusion in the literature, that forensic advancements appear to be the most common driver of cold cases and thus funding for the upkeep and preservation of these samples is critical (1,16,75,76).

3.2. General Structure

The general structure of cold case reviews is discussed by Allsop (1). The flow of these reviews include locating original paperwork with any subsequent reviews, and investigation into potential exhibits that may be utilised for forensic testing (1). In addition, investigation into previous closing statements may identify potential suspects, and if so, forensics is utilised as a tool to link them (1). A cold case review team in the UK, over an 8-month review period, noted that none of the 27 reviewed murders resulted in progression (1). Consequently, a stranger rape review did result in prosecution, and more cold case stranger rapes have resulted in conviction since the team began (1). This is also the general structure that is utilised in the USA, with the location and reviewing of documentation, identifying potential exhibits and forming an investigative plan, including forensic reviews (16). However, there are some discrepancies between the USA and UK that have been discussed. Additionally, the lack of cold case teams and issues in distribution of funding is noted across studies in the USA and UK (1,16,74-76).

3.2.1. Discrepancies

Some of the most apparent differences in cold case review structure are noted within the USA (16). The USA brings in the concepts of neighbourhood canvassing and scene inspections (16). This respectively entails door to door knocking, and interviews of persons on the street of which an incident occurred (16). These can be revisited later if the case turns cold, to locate potential witnesses, in order to pursue leads (16). It was also commonly found that if no one at the time answered the door, officers would not follow up (16). This is an issue as this may have provided relevant information at the time to assist the investigation and progress it further.

The effectiveness of cold case units has been discussed within the literature. Walton and Pettem (16) identified the formation of cold case units in long-term missing persons cases, that included experienced investigators, resulted in success across different agencies. This supports the notion for investing funding into cold case units on a universal scale. In addition, they noted that the USA collaborates at federal, state/local and volunteer levels, with access to numerous databases, that has also been associated with solvability in cold cases (16,74). The use of unfunded cold case review teams containing a board of interdisciplinary experts, meeting 2 to 4 times a year, occurs at the state and local level (1,16,74-76). However, the success of these teams has not been discussed, further advocating for more research into this area across police agencies (1,16,74-76).

Another unique factor to the USA is the use of cold case playing cards (16). This idea was formed by an agent in Florida and involves a stack of regular playing cards containing information on unsolved homicides and long-term missing persons, along with a photograph of the victims (16). These were distributed to Florida state prisons, and due to high success

rates, were further distributed to troops in Iraq, and then broadened to form state wide decks with 104 unsolved cases (16). These decks were distributed to 129 state prisons and consequently further distributed to other states in the USA, and was additionally adopted in Queensland, Australia (16). It would appear that homicides and missing persons carry more weight, and therefore, validate the resources invested in them (16). Therefore, this may be a cost-efficient method to bring about progression in cold cases on an international scale.

The final unique factor to the USA is the use of volunteers (16). Due to the lack of resources invested into cold cases, use of volunteers could be an invaluable tool for their progression. These volunteers include people from varied professions, ages, and backgrounds which, if utilised correctly can optimise progression of cases (16). These volunteers are broken into desk workers and field workers (16). Examples of field work volunteers include the Vidocq Society, which is a review team that meet monthly to look into unsolved homicides around the nation (16). Additionally, Texas EquuSearch are mounted and on foot search teams funded by donations, with proven success rates, with 300 people returned to their families, and the discovery of at least 103 missing persons remains (16). The last example is Ralston and Associates, which are an underwater search team, volunteering for around 30 years (16). This team travel throughout USA and Canada searching for drowning victims, with proven success, as since 1983, they have recovered over 90 human remains (16). The success of volunteers and the lack of funding required, would seemingly appear to be one of the most beneficial tools that could be adopted on a global scale to further cold cases.

Unique to the UK is the concept of an omnicompetent homicide investigator, that handle both live and cold case equally (76). These investigators have to be trained and experienced in homicide investigations (76). The ACPO manual maintains they must be skilled and experienced and are under a professional development scheme to be updated on skills, including knowledge of forensic science, crime scene examination, and behavioural sciences, to improve investigations (76). However, it is noted that the ACPO manual has sufficient lack of direction on conducting cold case reviews, with a process chart dating back to 1998 being the only available guide (76). Therefore, an updated version is required, particularly with the lack of universal approaches to conducting cold case reviews noted throughout the literature.

Another factor unique to the UK is the use of progressive reviews, carried out periodically, ensuring all investigative opportunities have been explored, and are ideally conducted every 2 years, depending on availability of resources (1). Conclusively, the authors determine that dedicated review teams and resources, particularly government funding, offer the highest success rates for solving cold cases (1).

Research into the effectiveness of cold case work has been conducted within the literature. The general findings of a study by Davis et al. (74) regarding case work, personnel, funding and success rates in the USA, were mixed. Of those conducting cold case work, 20% have an established protocol for initiation of these cases, 10% have dedicated investigators, and a mere 7% have a designated unit (74). In addition, they also noted that the main source of funding is provided by grants (74). More importantly, the success rates appear low, with only 20% of cases being cleared, 5% resulting in arrest, and 1% resulting in conviction (74). The factors identified for higher clearance rates were level of funding, and access to

investigative databases (74). In addition, there is a lack of tracking on conviction rates, and overall efficiency of investigations, including: court filings, sentencing, time spent on cases in relation to number of clearances, concluding that cost effectiveness and conviction rates are areas requiring more attention (74).

There has been significant research conducted into cold case reviews in both the USA and UK, in terms of the differences and similarities noted within their structure (1,16,74-76). Overall, it would appear the general workflow structure between the USA and UK are similar. However, the lack of cold case units across the USA and UK incorporating experts from multiple disciplines, and the lack of knowledge surrounding the effectiveness of cold case reviews, all suggest that further research is required to determine the best structure for conducting cold case reviews, in order to obtain convictions.

3.3. Areas for Improvement

It is apparent from the literature that the main issues in resolving cold cases stems from: budgeting, distribution of resources, actions of previous investigators (i.e., evidence collection, preservation and foresight for forensic advancements), lack of record keeping of cases successes (i.e., resulted in conviction) vs. time and resources invested, and lastly the lack of incorporation of experts from varied fields in forensic and behavioural sciences as permanent cold case staff to assist investigators with their expertise (1,16,74-76).

In order to overcome or improve these areas, it is critical that cold case units track the success rates of the investments into cold cases, more importantly the likelihood of cases resulting in a conviction (74). This reinforces the requirement of interdisciplinary support in cold case teams, such as the incorporation of prosecutors to advise on likelihood

of conviction prior to re-opening cases, thus, appropriately distributing resources to those that have a potentially higher success rate (74).

Of those cases where sufficient forensic evidence was collected, it is essential to invest resources into the correct storage and preservation of these samples, to prevent them from degradation, particularly with DNA samples (11,74). Exposure of DNA to moisture can ultimately degrade these samples, rendering them unusable (11,74). Lastly, with reference to forensic samples, the order of testing is critical, and should be carried out from least to most destructive, in order to maximise the evidence (11). This can be carried out via communicating with forensic experts in multiple departments, where obtaining one type of evidence may need to be prioritised over the other in order to link an offender to the crime (11). Overall, these improvements may assist with the declining clearance rates, and knowledge of these factors may prevent other active cases from becoming cold cases.

4. CONCLUSION

Conclusively, it is evident from the literature that there are discrepancies surrounding the knowledge of solvability factors in homicides, including the 48-hour period, body disposal location, forensic awareness of the offender, and decomposition rates and the factors that alter these. However, it is apparent that critical factors affecting solvability and evidence collection include: time taken to recovery a body, bodies disposed of in outdoor locations and the associative affects of temperature and insect activity on decomposition, forensic awareness of an offender, and the resulting impact of the CSI effect in increasing the prosecutions burden of proof. Overall, it is evident from the literature that there is a lack of research that explicitly investigates the time between estimated death and

recovery and murder and disposal locations on solvability, particularly regarding cases recovered from water. These locations require further studies in order to assist investigators on the time-critical periods and associated forensic implications for evidence collection, and distribution of resources, with the outcome of preventing active cases from becoming cold cases.

4.1. Project Brief and Aims

The aim of this study is to address this specific research gap, with the ultimate aim of providing law enforcement agencies with specific information surrounding the murder and disposal locations that require the most focus in missing persons or homicide investigations, and the associated implications on forensic evidence. This research could aid investigators in the distribution of resources, and time-critical locations, to ultimately positively impact the outcome of cases, due to the physical evidence requirements for case progression. A further intended outcome of this research is to highlight the benefit of cold case detectives working in collaboration with specialists to form cold case task forces and share expertise.

This research will be carried out by undertaking statistical analyses on true crime solved case data of 54 North American serial killers active between 1920 and 2016, and a total of 125 solved cases, to identify if there are any statistically significant trends between murder and disposal location and estimated time between death and recovery, when broken down into indoor and outdoor cases and 8 specified time series.

5. REFERENCES

1. Allsop C. Cold Case Homicide Reviews. In: Hoboken, NJ, USA: John Wiley & Sons, Inc; 2017. p. 566-77
2. Reale K, Beauregard E. Body Recovery After the "First 48": Implications for Sexual Homicide Investigations. Homicide Studies. 2018:1088767918795209.
3. Brown KM, Keppel RD. Child Abduction Murder: The Impact of Forensic Evidence on Solvability. Journal of Forensic Sciences. 2012;57(2):353-63.
4. Mouzos J, Muller D. Solvability factors of homicide in Australia: An exploratory analysis. Canberra: Australian Institute of Criminology. 2001;(216):1-6.
5. Brown KM, Keppel RD. Child Abduction Murder: An Analysis of the Effect of Time and Distance Separation Between Murder Incident Sites on Solvability. Journal of Forensic Sciences. 2007;52(1):137-45.
6. Beauregard E, Martineau M. No body, no crime? The role of forensic awareness in avoiding police detection in cases of sexual homicide. Journal of Criminal Justice. 2014;42(2):213-20.
7. DiBiase TA. No-Body Homicide Cases: A Practical Guide to Investigating, Prosecuting, and Winning Cases When the Victim is Missing. ProtoView. 2015;2(7).
8. Hanfland KA, Keppel RD, Weis JG. Case management for missing children homicide investigation: Executive summary. Homicide Investigation and Tracking System, Attorney General of Washington; 1997 May.
9. Godwin M. VICTIM TARGET NETWORKS AS SOLVABILITY FACTORS IN SERIAL MURDER. Social Behaviour and Personality: an international journal. 1998;26(1):75-83.

10. Cockle DL, Bell LS. Human decomposition and the reliability of a 'Universal' model for post mortem interval estimations. Forensic Science International. 2015;253:136.e1,136.e9.
11. Lee HC, Palmbach T, Miller MT. Henry Lee's crime scene handbook. Academic Press; 2001 Jul 25.
12. Rutty GN, Hopwood A, Tucker V. The effectiveness of protective clothing in the reduction of potential DNA contamination of the scene of crime. International journal of legal medicine. 2003 Jun 1;117(3):170-4.
13. DiBiase TA. No-body homicide cases: A practical guide to investigating, prosecuting, and winning cases when the victim is missing. CRC Press; 2014 Nov 17.
14. Danto BL, Bruhns J, Kutscher AH, Kutscher A. The human side of homicide. Columbia University Press; 1982.
15. Brown KM, Keppel RD. Child abduction murder: An analysis of the effect of time and distance separation between murder incident sites on solvability. Journal of forensic sciences. 2007 Jan;52(1):137-45.
16. Walton R, Pettem S. Investigation of Long-Term Missing Persons as Cold Case Homicides: An American Perspective. In Handbook of Missing Persons 2016 (pp. 233-249). Springer, Cham.
17. Carter DL. Homicide process mapping: Best practices for increasing homicide clearances. Institute for Intergovernmental Research; 2013.
18. Sewell JD. The stress of homicide investigations. Death studies. 1994 Nov 1;18(6):565-82.
19. Cotter A. Homicide in Canada, 2013. Juristat: Canadian Centre for Justice Statistics. 2014:1.

20. Pastia C, Davies G, Wu E. Factors influencing the probability of clearance and time to clearance of Canadian homicide cases, 1991-2011. Homicide studies. 2017 Aug;21(3):199-218.
21. LePard D, Demers S, Langan C, Kim Rossmo D. Challenges in serial murder investigations involving missing persons. Police practice and research. 2015 Jul 4;16(4):328-40.
22. Skinner M, Lazenby RA. Found! Human remains: A field manual for the recovery of the recent human skeleton. 1983.
23. Beauregard E, Martineau M. No body, no crime? The role of forensic awareness in avoiding police detection in cases of sexual homicide. Journal of Criminal Justice. 2014 Mar 1;42(2):213-20.
24. Beauregard E, Proulx J. Profiles in the offending process of nonserial sexual murderers. International Journal of Offender Therapy and Comparative Criminology. 2002 Aug;46(4):386-99.
25. Ressler RK, Burgess AW, Douglas JE. Sexual homicide: Patterns and motives. Simon and Schuster; 1988.
26. Ressler RK, Burgess AW, Douglas JE, Hartman CR, D'AGOSTINO RB. Sexual killers and their victims: Identifying patterns through crime scene analysis. Journal of Interpersonal Violence. 1986 Sep;1(3):288-308.
27. Beauregard E, Field J. Body disposal patterns of sexual murderers: Implications for offender profiling. Journal of Police and Criminal Psychology. 2008 Oct 1;23(2):81.
28. Addington LA. Using NIBRS murder data to evaluate clearance predictors: A research note. Homicide Studies. 2006;10:140-52.

29. Litwin KJ, Xu Y. The dynamic nature of homicide clearances: A multilevel model comparison of three time periods. Homicide Studies. 2007 May;11(2):94-114.
30. Mouzos J, Muller D. Solvability factors of homicide in Australia: An exploratory analysis. Canberra: Australian Institute of Criminology; 2001 Oct 1.
31. Wellford CF, Cronin JM, Brandl S, Bynum T, Eversen T, Galeria S. An Analysis of Variables Affecting the Clearance of Homicides: A Mutistate Study. Washington, DC: Justice Research and Statistics Association; 1999 Oct.
32. Regoeczi WC, Jarvis J, Riedel M. Clearing murders: Is it about time?. Journal of Research in Crime and Delinquency. 2008 May;45(2):142-62.
33. Beauregard E, Martineau M. A descriptive study of sexual homicide in Canada: Implications for police investigation. International journal of offender therapy and comparative criminology. 2013 Dec;57(12):1454-76.
34. Davies A. Rapists' behaviour: A three aspect model as a basis for analysis and the identification of serial crime. Forensic Science International. 1992 Aug 1;55(2):173-94.
35. Beauregard E, Bouchard M. Cleaning up your act: Forensic awareness as a detection avoidance strategy. Journal of Criminal Justice. 2010 Nov 1;38(6):1160-6.
36. Reale K, Beauregard E, Martineau M. Is investigative awareness a distinctive feature of sexual sadism?. Journal of interpersonal violence. 2017 Mar 1:0886260517698824.
37. Canter D, Youngs D. Principles of geographical offender profiling. Routledge; 2017 Mar 2.

38. Culatta E, Clay-Warner J, Boyle KM, Oshri A. Sexual revictimization: A routine activity theory explanation. Journal of interpersonal violence. 2017 Apr 1:0886260517704962.
39. Chan HC, Heide KM, Beauregard E. What propels sexual murderers: A proposed integrated theory of social learning and routine activities theories. International Journal of Offender Therapy and Comparative Criminology. 2011 Apr;55(2):228-50.
40. Cohen LE, Felson M. Social change and crime rate trends: A routine activity approach. American sociological review. 1979 Aug 1:588-608.
41. Rhineberger-Dunn G, Briggs SJ, Rader NE. The CSI Effect, DNA Discourse, and Popular Crime Dramas. Social Science Quarterly. 2017 Jun;98(2):532-47.
42. Heinrick J. Everyone's an expert: The CSI effect's negative impact on juries. The Triple Helix. 2006;3(1):59-61.
43. Lawson TF. Before the verdict and beyond the verdict: The CSI infection within modern criminal jury trials. Loy. U. Chi. LJ. 2009;41:119.
44. Maeder EM, Corbett R. Beyond frequency: Perceived realism and the CSI effect. Canadian Journal of Criminology and Criminal Justice. 2015 Jan;57(1):83-114.
45. Baskin DR, Sommers IB. Crime-show-viewing habits and public attitudes toward forensic evidence: The "CSI effect" revisited. Justice System Journal. 2010 Jan 1;31(1):97-113.
46. Brewer PR, Ley BL. Media use and public perceptions of DNA evidence. Science Communication. 2010 Mar;32(1):93-117.
47. Hayes-Smith RM, Levett LM. JURY'S STILL OUT: HOW TELEVISION AND CRIME SHOW VIEWING INFLUENCES JURORS'EVALUATIONS OF EVIDENCE. Applied Psychology in Criminal Justice. 2011 Mar 1;7(1).

48. Podlas K. The CSE Effect: Exposing the Media Myth. Fordham Intell. Prop. Media & Ent. LJ. 2005;16:429.
49. Schweitzer NJ, Saks MJ. The CSI effect: Popular fiction about forensic science affects the public's expectations about real forensic science. Jurimetrics. 2006;47:357.
50. Shelton DE, Kim YS, Barak G. A study of juror expectations and demands concerning scientific evidence: Does the CSI effect exist. Vand. J. Ent. & Tech. L.. 2006;9:331.
51. Kim YS, Barak G, Shelton DE. Examining the "CSI-effect" in the cases of circumstantial evidence and eyewitness testimony: Multivariate and path analyses. Journal of Criminal Justice. 2009 Sep 1;37(5):452-60.
52. Nolan A, Mead RJ, Maker G, Speers SJ. A review of the biochemical products produced during mammalian decomposition with the purpose of determining the post-mortem interval. Australian Journal of Forensic Sciences. 2019:1-12.
53. Goff ML. Early post-mortem changes and stages of decomposition in exposed cadavers. Experimental and Applied Acarology. 2009 Oct 1;49(1-2):21-36.
54. van Daalen MA, de Kat DS, Oude Grotebevelsborg BF, De Leeuwe R, Warnaar J, Oostra RJ, M Duijst-Heesters WL. An aquatic decomposition scoring method to potentially predict the postmortem submersion interval of bodies recovered from the North Sea. Journal of forensic sciences. 2017 Mar;62(2):369-73.
55. Megyesi MS, Nawrocki SP, Haskell NH. Using accumulated degree-days to estimate the postmortem interval from decomposed human remains. Journal of Forensic Science. 2005 Apr 6;50(3):1-9.
56. Galloway A, Birkby WH, Jones AM, Henry TE, Parks BO. Decay rates of human remains in an arid environment. Journal of Forensic Science. 1989 May 1;34(3):607-16.

57. Reijnen G, Gelderman HT, Oude Grotebevelsborg, Bernice F. L, Reijnders UJL, Duijst, Wilma L. J. M. The correlation between the Aquatic Decomposition Score (ADS) and the post-mortem submersion interval measured in Accumulated Degree Days (ADD) in bodies recovered from fresh water. Forensic Science, Medicine and Pathology. 2018;14(3):301-6.
58. Cockle DL, Bell LS. Human decomposition and the reliability of a 'Universal' model for post mortem interval estimations. Forensic science international. 2015 Aug 1;253:136-e1.
59. Ritchie GT. A comparison of human decomposition in an indoor and an outdoor environment.
60. Komar DA. Decay rates in a cold climate region: a review of cases involving advanced decomposition from the Medical Examiner's Office in Edmonton, Alberta. Journal of Forensic Science. 1998 Jan 1;43(1):57-61.
61. Micozzi MS. Experimental study of postmortem change under field conditions: effects of freezing, thawing, and mechanical injury. Journal of Forensic Science. 1986 Jul 1;31(3):953-61.
62. Cockle DL. Human decomposition and the factors that affect it: a retrospective study of death scenes in Canada (Doctoral dissertation, Environment: Department of Archaeology).
63. Anderson GS. Comparison of decomposition rates and faunal colonization of carrion in indoor and outdoor environments. Journal of Forensic sciences. 2011 Jan 1;56(1):136-42.

64. Keough N, Myburgh J, Steyn M. Scoring of decomposition: a proposed amendment to the method when using a pig model for human studies. Journal of forensic sciences. 2017 Jul;62(4):986-93.
65. Schroeder H, Klotzbach H, Oesterhelweg L, Püschel K. Larder beetles (Coleoptera, Dermestidae) as an accelerating factor for decomposition of a human corpse. Forensic Science International. 2002 Jul 17;127(3):231-6.
66. Ceciliason AS, Andersson MG, Lindström A, Sandler H. Quantifying human decomposition in an indoor setting and implications for postmortem interval estimation. Forensic science international. 2018 Feb 1;283:180-9.
67. Roberts LG, Spencer JR, Dabbs GR. The effect of body mass on outdoor adult human decomposition. Journal of forensic sciences. 2017 Sep;62(5):1145-50.
68. Mann RW, Bass WM, Meadows L. Time since death and decomposition of the human body: variables and observations in case and experimental field studies. Journal of Forensic Science. 1990 Jan 1;35(1):103-11.
69. Hewadikaram KA, Goff ML. Effect of carcass size on rate of decomposition and arthropod succession patterns. The American Journal of Forensic Medicine and Pathology. 1991 Sep;12(3):235-40.
70. Zhou C, Byard RW. Factors and processes causing accelerated decomposition in human cadavers–an overview. Journal of forensic and legal medicine. 2011 Jan 1;18(1):6-9.
71. Campobasso CP, Di Vella G, Introna F. Factors affecting decomposition and Diptera colonization. Forensic science international. 2001 Aug 15;120(1-2):18-27.

72. Spicka A, Johnson R, Bushing J, Higley LG, Carter DO. Carcass mass can influence rate of decomposition and release of ninhydrin-reactive nitrogen into gravesoil. Forensic science international. 2011 Jun 15;209(1-3):80-5.
73. Matuszewski S, Konwerski S, Frątczak K, Szafałowicz M. Effect of body mass and clothing on decomposition of pig carcasses. International journal of legal medicine. 2014 Nov 1;128(6):1039-48.
74. Davis RC, Jensen C, Kitchens KE. Cold-Case Investigations. RAND Corporation; 2011.
75. Allsop C. Motivations, money and modern policing: accounting for cold case reviews in an age of austerity. Policing and Society. 2013 Sep 1;23(3):362-75.
76. Atkin H, Roach J. Spot the difference: Comparing current and historic homicide investigations in the UK. Journal of Cold Case Review. 2015;1(1):5-21.

Part Two

Manuscript

An Investigation into Summary Data of Solved North American Serial Killer Cases to Identify Trends within Murder and Disposal Locations and Time Between Estimated Death and Recovery

Masters in Forensic Science Manuscript

An Investigation into Summary Data of Solved North American Serial Killer Cases to Identify Trends within Murder and Disposal Locations and Time Between Estimated Death and Recovery

By

Cody Raymer

A manuscript submitted as part of the requirements for the unit

BIO612

Master of Forensic Science (Professional Practice)

in

The School of Veterinary and Life Sciences

Murdoch University

Supervisors:

Dr. David Keatley (Murdoch University)

Brendan Chapman (Murdoch University)

Semester 1, 2019

ABSTRACT

Homicide investigations require significant resources and personnel from multiple departments; therefore, it is critical to be thorough and explore all lines of inquiry to ensure these cases do not turn cold. Cases are generally considered cold when all lines of inquiry have been explored and there are no further investigative opportunities, therefore, the actions taken within the early stages of an investigation are critical to their solvability. Many factors have been identified in association with solvability, include; body disposal locations, forensic awareness of the offender, the distance between murder and body recovery location, and the time elapsed between death and recovery. However, there is a lack of research explicitly investigating the time between estimated death and recovery and murder and disposal locations on solvability, particularly concerning cases recovered from water. Therefore, the aim of this study was to undertake statistical analyses on true crime solved case data of 54 North American serial killers active between 1920 and 2016 and a total of 125 solved cases, to identify if there are any statistically significant trends between the aforementioned variables, when broken down into indoor and outdoor cases and 8 specified time series. The findings deduced that bodies recovered at 48 hours and above are discovered in outdoor locations, whereas, those discovered within 24 hours are generally found inside the victim's residence, and water disposal cases were mainly recovered over 7 days. The result of this work will guide law enforcement in identifying critical locations to investigate in missing persons or homicide cases that are associated with delayed recovery, and more importantly provide insight into not only the forensic implications associated with recovery prolonged after 48 hours, but also offer some insight into the type of offenders that commit these crimes.

TABLE OF CONTENTS

Keywords

Sexual homicides, solvability, body disposal, 48 hours

List of Figures

List of Tables

List of Abbreviations

ALS – alternate light source

AP – acid phosphatase

PMI – post-mortem interval

MO – modus operandi

PPE – personal protective equipment

1. INTRODUCTION

When conducting homicide investigations, it is crucial to be thorough and explore all avenues of inquiry to prevent them from becoming cold cases (1). Cases are generally considered cold when all lines of inquiry have been explored and there are no further investigative opportunities, therefore, the actions taken within the early stages of an investigation are critical to their solvability (1). Within homicide investigations, many criminological and forensic factors have been identified to substantially influence solvability, including victim-offender relationship, marital status of the offender, the distance between the incident site and body recovery location, time taken to locate the body and availability of resources within police departments (2,3,4). Of these factors, time has been identified as one of the most critical components in the resolution of homicide investigations, with a significant emphasis placed on the first 48-hours in law enforcement training (2,5). This period is particularly crucial due to the surrounding implications on; evidence degradation and finding leads and apprehending offenders, due to loss of information and vital evidence, particularly in incidences where a body has not yet been located (6,7,8).

Locating the body of a victim in many cases may be the only physical evidence available, and it has shown that some prosecutors will not go to trial without a body, placing significant importance on physical evidence in court trials (2,9). The absence of a body may be due to several factors regarding the location in which they were disposed of, including rate of decomposition, weather conditions, submersion in water, etc. (10). Without the identification of a body and disposal site, there are limitations for evidence collection, and even if these sites are located, they may have already suffered from tampering or contamination (2,10).

The location in which a body is disposed of manifests its own forensic difficulties, including; weather conditions, rate of decomposition, and the resultant effects it may have on evidence collection (10). Rate of decomposition is heavily influenced by the environment in which a body is found, where research has indicated that temperature and moisture are significant contributors to the biochemical processes of decomposition (10). Bodies exposed to factors that accelerate decomposition such as; increased temperature and moisture, increased exposure to insect activity, and higher body weight will hinder evidence collection, such as post-mortem details of wound analysis and time of death estimation, which may ultimately aid investigators in indicating foul play has occurred or linking similar cases (2,10). In addition, whether a body is located indoors or outdoors may have a significant impact on the collection of evidence types such as; fingerprints, impressions, and DNA (11). Exposure to outdoor conditions such as significant rain or UV may ultimately degrade or abolish evidence, such as specific class and individualizing characteristics in impressions and fingerprints, and also degrade DNA (11). By contrast, victims located indoors may result in better collection and preservation of evidence and reduce the chances of tampering and contamination occurring (10,11).

Tampering may occur from animal or scavenging activity or be due to an offender returning to the scene to interfere with it or the body, in an attempt to manipulate or "stage" the scene to avoid detection (11,12). Contamination can arise from contact between; personnel and evidence, between evidence types, or between evidence of different crime scenes (11). The reduction of contamination is highly essential as forensic science progresses, particularly with the sensitivity of DNA kits increasing, and the ability to detect as little as 100 pg of DNA, which may ultimately result in inadmissibility in court and miscarriages of justice (11,13). To reduce the likelihood of contamination occurring, first

responders and personnel at scenes should ensure PPE is worn, gloves are changed between exhibits, exhibits should be packaged and transported by different personnel, and maintain a proper chain of custody (11). The significant emphasis on evidence collection, storage, and transport protocol is important due to the shift in focus for the requirement of physical evidence to prosecute offenders (2).

It is evident that there is a lack of research explicitly investigating the time between estimated death and recovery and murder and disposal locations on solvability, particularly regarding cases recovered from water. Therefore, the purpose of this research was to undertake statistical analyses on true crime solved case data of 54 North American serial killers active between 1920 and 2016 and a total of 125 solved cases, to identify if there are any statistically significant trends between murder and disposal location and estimated time between death and recovery, when broken down into indoor and outdoor cases and 8 specified time series.

The ultimate aim of this study is to provide law enforcement agencies with specific information surrounding the murder and disposal locations that require the most significant focus in missing persons, or homicide investigations due to the associated implications on forensic evidence. This research will aid investigators in the distribution of resources and time-critical locations to ultimately positively impact the outcome of investigations, specifically due to the shift of focus to physical evidence requirements in cases.

2. MATERIALS AND METHODS

2.1. Sampling

From the original serial killer database, a subset of 54 of the original 4803 serial murderers, and their respective victims were utilized for this research. These murderers were selected based on the premise that their crimes were committed in North America, and all of the selected sample were males. A total of 125 solved cases were selected based on the most descriptive information provided for murder location, disposal location, and time taken between estimated death and body recovery. Solved cases for the purposes of this study were those that resulted in a conviction, and also included those where more than one offender had been convicted on the same offense. The information provided in this database was derived from police files, court reports, and media reports, and all information added was independently replicated. The factors being investigated included both the murder and body recovery site and the number of days between estimated death and discovery in determining if there are any significant trends found amongst the data. The murder and body recovery locations were further subdivided into indoor and outdoor categories as described below.

2.2. Variables

The variables being investigated are designated as murder and body disposal location, and time taken between estimated death and body discovery. Murder and body disposal locations were further divided into subcategories of indoor and outdoor locations, depicted in Table 1.

Table 1 - Frequency counts in percent (%) of the total distribution of 125 cases between designated indoor and outdoor subcategories for both murder and disposal locations.

Variables	Murder Location % (n)	Disposal Location % (n)
Indoor		
Own Dwelling	26.4 (33)	22.4 (28)
Other Dwelling	24.0 (30)	12.0 (15)
Other	6.4 (8)	4.8 (6)
Outdoor		
Other Dwelling	3.2 (4)	4.8 (6)
Water	0 (0)	4.8 (6)
Open	17.6 (22)	24.8 (31)
Closed	13.6 (17)	26.4 (33)
Car	8.8 (11)	0 (0)

The chi-square analyses that was carried out between both murder and disposal location, and time between estimated death and recovery both fell below p=.05 (p=.000 for both), indicating statistical significance between these variables. From this table (Table 1), it is apparent that the largest frequency of murder locations occurs inside the victim's dwelling, and by contrast, the most frequent disposal location occurs in outdoor closed locations, at the same frequency (26.4%). These findings would also indicate that bodies are moved from their original murder location in some cases.

For this study, own dwelling locations are designated as the victim's residence (i.e., inside or outside their residence). Other dwelling locations are specified as either the murderer's or any other individual's residence. Other locations are designated as public buildings (e.g., shopping centres, courthouse lobby's, etc.). Car locations are specified as either inside or outside of a vehicle, non-specific to the owner. Water locations in this study are designated as any body of water, including; rivers, creeks, bayou, culverts, etc. Outdoor open areas are identified as those that are accessible public venues that are readily visible, including; paths, main roads, near dumpsters or buildings, open parks, neighbourhoods, etc. In contrast, outdoor closed areas are public areas that are less readily accessible, have more shelter and are less frequently visited, including; bushland, ditches, shallow graves, side roads and hiking trails, mountains, alleyways, national parks, under bridges, etc.

The other variable being investigated in this study is estimated time between death and body recovery, which was coded as a continuous variable (0= <24 h, 1= <48 h, 2= <72 h, 3= <96 h, 4= <120 h, 5= <144 h, 6= < 1 week, 7= >1 week). However, it is important to note that cases found over a week old, ranged from weeks to 20 years, between death and recovery. This was carried out to reflect a larger number of time thresholds and determine if there is any time series that is statistically significant for the solvability of cases, and if so, whether that is reflective of forensic and criminological issues relevant to that time period. The overall range of time between estimated death and body recovery was 0-7,300 days.

2.3. Data interpretation and analysis

This study utilized IBM® SPSS Statistics 24.0 software for data analysis. The data was analysed utilizing chi-square analyses. The variables that were compared were disposal location and time between estimated death and recovery. The cut off for significant data was set at p=<.05. In addition, descriptive frequency statistics were carried out to identify trends across both murder and disposal locations and estimated time between death and recovery.

3. RESULTS

Table 2 represents the total percentage of cases designated at each time series at each given location. The highest proportion and variance of cases fall under <24 h (25.6%), <48 h (20%) and >7 days (40.8%). Most cases located within 24 hours were found inside the victim's residence (14.4%), whereas the smallest proportion of cases were located in outdoor closed locations (0.8%). However, a shift is noted between cases located within 24 hours and those within 48 hours, where the highest percentage of cases in the latter were discovered in outdoor open areas (10.4%). Cases found after 48 hours are predominately discovered in both outdoor open and closed locations, with the largest proportion of cases being discovered in outdoor closed locations after 96 hours (<120 h to >7 days). Overall, the highest levels of significant differences are observed between bodies discovered within 24 hours and those over 7 days, where the trends essentially reverse.

Table 2 - Total number of cases in percent (%) found within the respective time series for each variable for disposal locations, (N=125).

Variable	<24 h % (n)	<48 h % (n)	<72 h % (n)	<96 h % (n)	<120 h % (n)	<144 h % (n)	<7 days % (n)	>7 days % (n)	Total % (n)
Indoor									
Other	3.2 (4)	1.6 (2)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	4.8 (6)
Other Dwelling	2.4 (3)	0.8 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	8.8 (11)	12 (15)
Own Dwelling	14.4 (18)	5.6 (7)	0.8 (1)	0.8 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.8 (1)	22.4 (28)
Outdoor									
Closed	0.8 (1)	1.6 (2)	1.6 (2)	1.6 (2)	3.2 (4)	0.0 (0)	0.8 (1)	16.8 (21)	26.4 (33)
Open	4.8 (6)	10.4 (13)	1.6 (2)	1.6 (2)	0.0 (0)	0.0 (0)	0.0 (0)	6.4 (8)	24.8 (31)
Other Dwelling	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	4.8 (6)	4.8 (6)
Water	0.0 (0)	0.0 (0)	0.0 (0)	0.8 (1)	0.0 (0)	0.0 (0)	0.8 (1)	3.2 (4)	4.8 (6)
Total % (n)	25.6 (32)	20 (25)	4 (5)	4.8 (6)	3.2 (4)	0.0 (0)	1.6 (2)	40.8 (51)	100 (125)

Table 3 depicts the overall distribution of indoor, outdoor, and water cases found within the time series, with the highest variation at <24 h, <48 h and >7 days. From this data, it is evident that the highest proportion of cases discovered indoors are discovered within 24 hours (78.1%). By contrast, from <48 hours through to over 7 days, the largest proportion of cases are found in outdoor locations at respectively 60% and 76.5%. The most significant shift amongst these cases is evident in those identified after 7 days, where most cases were

found in outdoor closed locations (41.2%), by comparison, only 2% of cases were found inside the victim's residence after this elapsed period. In addition, all water cases in this data were discovered after 7 days. Although the number of water disposal cases is minimal (4), it may still indicate that water disposal is significant for delayed recovery. These findings would reiterate that bodies disposed of in outdoor concealed areas will delay body recovery. It is also important to note that the overall largest number of cases are represented over 7 days (51) compared to the smallest number of cases in 48 hours (25) and 24 hours (32), which should be considered when interpreting the data.

Table 3 - Cumulative percent (%) of the distribution of indoor, outdoor and water disposal location cases found within <24 h, <48 h and >7 days, (N=108) based on the proportion of cases distributed amongst <24 h, <48 h and >7 days, respectively at 32, 2

Variable	<24 h (%) (n=32)	<48 h (%) (n=25)	>7 days (%) (n=51)
Indoor			
Other	12.5	8.0	0
Other Dwelling	9.4	4.0	21.5
Own Dwelling	56.2	28.0	2.0
Outdoor			
Closed	3.1	8.0	41.2
Open	18.8	52.0	15.7
Other Dwelling	0	0	11.8
Water	0	0	7.8
Total (%)	100	100	100

Figure 1 represents the total cumulative indoor, outdoor, and water cases described in Table 3, for bodies recovered within 24 h, 48 h, and over 7 days. As recovery time is delayed, the incidence of indoor cases decreased from 78.1% to 23.5%, and by contrast, the incidence of outdoor cases increased from 21.9% to 76.5% across these specified time series.

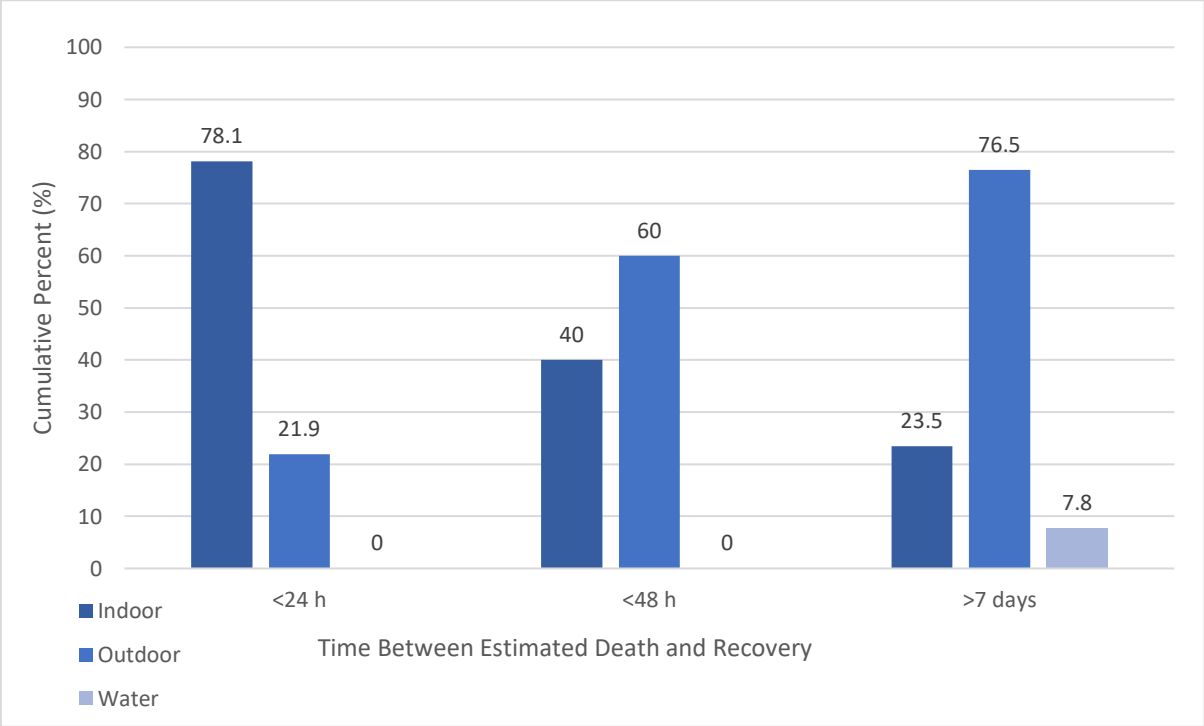

Figure 1 *- Total Cumulative Percent (%) of Indoor, Outdoor, and Water cases found within 24 hours, 48 hours and over 7 days*

Table 4 represents the comparison of cases where the murder and disposal location remain the same, versus cases where the murder and disposal locations differ. The most obvious difference is observed within indoor cases remaining in the same murder location, with 75.5% found within 7 days. By comparison, in cases discovered outdoors (moved and unmoved), there appears to be no difference in time between estimated death and recovery. These cases are approximately evenly split between cases found within 7 days and over 7 days, with no observable trends. The lack of cases moved indoors may be of significance and provide information about the characteristics of the offender.

Table 4 - Comparison of time between death and recovery for both <7 days and > 7 days between cases maintain the same murder location vs. those that have been moved to a different disposal location for cumulative indoor and outdoor locations. The time series of <7 days for this table is the cumulative total of all cases between <24 h and <7 days (74 cases), where N=125.

Case Location	*<7 days*	*>7 days*	*Total*
Not Moved			
Indoor	37	12	49
Outdoor	14	16	30
Moved			
Indoor	0	0	0
Outdoor	23	23	46
Total	74	51	125

4. DISCUSSION

4.1. Body location and time between estimated death and recovery

Across the data, the general trends observed were that as the time between estimated death and recovery increased, the location of cases found indoors decreased, and those outdoors increased (Tables 1, 2 & 3, Figure 1). Of the 125 solved cases utilized in this data, the majority of cases located within 24 hours, were discovered inside the victim's residence, which was also identified as the most observed murder location (Table 1 & 2). The shift from indoor to outdoor discovery was observed in cases found within 48 hours, which were predominately discovered in outdoor open areas, i.e., more accessible and visible, such as main roads (Table 2). Thereafter, most cases were found over 7 days in

outdoor closed locations, i.e., more concealed and less visible, such as woodlands, under bridges, etc., which was also noted as the most observed disposal location (Table 1 & 2). Notably, 80% of water cases were also discovered after 7 days (Table 2). It was deduced from the data that the most apparent critical time periods were <24 h, <48 h and over 7 days, where 108 out of the 125 cases were observed (Table 3).

Studies have indicated that homicides committed indoors are typically easier to solve compared to those occurring outdoors, due to the better preservation and therefore quality of evidence (14-18). This research could explain the solvability of cases discovered within 24 hours that occurred inside the victim's own residence (Tables 1 & 2). When an individual goes missing, the victim's residence would be a priority location in an investigation, therefore enhancing recovery time and thus associated evidence collection (14-18). In addition, early body recovery observed in the data (Tables 1 & 2) may be owing to the offender leaving the body at the scene, rather than trying to dispose of the body (6,19). These actions may provide information on the characteristics of the offender, i.e., whether they are organized or disorganized killers, and indication of any forensic awareness (6,19).

Further similarities are observed with a study conducted by Reale and Beauregard (2) which found that victims disposed of in their own home were discovered within 48 hours in 66.7% of cases, and those recovered from public locations were found within 48 hours in 75% of cases. However, their study primarily focused on the 48-hour period. Therefore, it could not be said whether the cases discovered indoors were explicitly found within 48 hours, or if they were discovered earlier (2). Ultimately, the Reale and Beauregard (2) findings similarly reflect the higher number of observed cases in this study found inside the victim's residence within 24 hours (56.2%), and those in outdoor open locations within 48

hours (52.0%) (Table 2). The lower percentages in this study (56.2% and 52.0%) could be due to the more extensive time series and therefore, distribution of cases. Overall, the general consistencies validate the importance of the early recovery of bodies, specifically within 48-hours, and associative evidence collection for solvability of cases (2).

By contrast the findings of this study (Table 2) were not consistent for bodies discovered outdoors, as most cases were discovered after 48 hours (83.1%) (Table 2), whereas, Reale and Beauregard (2) indicate victims discovered outdoors were located evenly within 48 hours and over 48 hours. However, they did note that outdoor locations as contact scenes slightly delay body recovery over 48 hours (2). Their findings may indicate that the primary contact or murder scene has more statistical significance on solvability than disposal site, which has been identified as an understudied factor within the literature (2,8). Another factor to consider that may explain these differences is the utilization of 250 Canadian cases in the Reale and Beauregard (2) study, versus the use of 125 North American cases in this study. There may be notable geographical differences within crime patterns and behaviors between North America and Canada. This notion is supported by Beauregard and Bouchard (20) that noted differences between MOs in sexually motivated offenders across different geographical locations. They found that Belgium offenders exhibited a higher incidence of vaginal intercourse compared to UK, Scotland, Germany, and Finland offenders (20). Therefore, this reinforces the requirement for future research into the effects of murder and disposal location, and time between estimated death and recovery, by incorporating cases on a global scale to observe whether there are notable independent geographical trends (20).

Another important factor in homicide case solvability is the collection and preservation of evidence, as research has indicated that forensic evidence is heavily relied upon in court (2,9). This reliance partially stems from the impact of the CSI effect on juries, where popular TV shows such as CSI and Law & Order have skewed the way forensic science, and more specifically the use of DNA, is portrayed (21-25). This influence on jurors can negatively impact trials, as it is shown that without DNA evidence, they are more unwilling to convict (21-25). Therefore, factors that can significantly affect the quality of different evidence types (fingerprints, DNA, impressions, etc.) and ultimately affect the solvability of homicide cases, including the rate of decomposition, weather conditions and submersion in water, should be considered when conducting an investigation (26).

Rate of decomposition is heavily influenced by several factors, including temperature, insect activity, and body weight (27-30). Increased temperature, insect activity, and body weight are all associated with the acceleration of decomposition and therefore, the ultimate loss of evidence (27-30). The general trend of prolonged recovery and disposal in outdoor locations (Figure 1) could be impacted by the effects of decomposition (27). For example, if cases were discovered outdoors in summer periods, this may have accelerated decomposition by an increase in insect activity and colonization, therefore, increasing body temperature further, and reducing the quality of evidence that could be recovered, such as wound analysis details, and estimated time since death (PMI) to identify whether foul play has occurred (2,10,27-29). Estimated time since death (PMI) is known to be influenced by temperature, indicating that cases found in higher temperatures are often over-estimated and those in colder conditions are often under-estimated (27,31-32).

Severe weather conditions can also impact forensic evidence, wherein heavy rain, fingerprints, DNA, and impression evidence collection are compromised, as class and individualizing characteristics are abolished, and DNA evidence is degraded (11, 33, 34). Essentially, this may explain the solvability of cases found within 24 hours in indoor locations (Figure 1), as evidence may have been better preserved and protected from these degrading factors, in comparison to the observed delay in recovery in cases found outdoors (Figure 1).

The discovery of the majority of water cases after 7 days may be associated with rate of decomposition. The body begins to bloat and accumulate gas between 3 to 10 days, meaning that prolonged recovery (Figure 1) could be due to the body being submerged in water, and resurfacing during this bloat period (27). However, this is not conclusive as decomposition is highly variable, and therefore, further studies would be required (27-30).

The inability to recover or locate bodies may explain the underrepresentation of water cases in this study (Table 2). Research has shown that recovery of a body may be the only physical evidence relating to a case (2,10). In the absence of a body, associated forensic evidence that will help further cases and result in convictions, such as DNA, fingerprints, fibres, etc., also remain absent (33,34). Studies conducted on the preservation of different biological samples (blood, saliva, sperm) in water, have indicated that prolonged immersion resulted in increased DNA degradation, and therefore, the inability to obtain DNA profiles (33,34). More specifically, indication of spermatozoa through traditional forensic based identification methods, including alternate light sources (ALS), acid phosphatase (AP) tests, and microscopy examination, for most samples, were hindered (33,34). ALS and AP tests returned negative results for most samples beyond 24 hours, and spermatozoa were found mainly undetectable beyond 12 hours (33,34). The findings of these studies (33,34) and the

data represented in this study (Tables 2 & 3) emphasize the importance of body recovery within 24 hours for solvability. It also highlights the potential issues for the recovery of DNA in water cases beyond 7 days (Table 2). However, the cases utilized in this study were solved, therefore, application of these variables to unsolved water cases would be required.

4.2. Body Disposal

A factor that has been identified in influencing homicide case solvability is forensic awareness strategies of an offender (2). These forensic awareness strategies include; adaptation of the offenders MO, destroying evidence, utilization of PPE, and moving a body from the original location to delay recovery and avoid apprehension (2,6,20). Moving the body from the original murder location was exhibited in the current findings (Table 4), however, of those moved, there was no distinguishable trend identified between bodies remaining in the same murder location, versus those that were moved for outdoor locations (Table 4). These were typically even for body recovery in less than 7 days and over 7 days (Table 4). These findings differed from Reale and Beauregard (2), which found that moving, disposal, and dismemberment of victims all delayed body recovery after 48 hours. This may be due to the difference in the geographical location of databases (North American vs. Canadian), their larger sample size (N=250 vs. N=125), or the focus of forensic awareness strategies in their study (2). Therefore, exploration of forensic awareness factors, with a higher number of cases (N=>125) would be required for further studies, to assess their impact on solvability.

The most apparent changes were observed between indoor moved and unmoved cases, where the majority of cases found within 7 days were observed in unmoved indoor murder locations (Table 4). However, notably, no cases were moved indoors from the original murder location (Table 4). These findings indicate that bodies murdered indoors, remained there, and there was no attempt to move a body from outdoor locations back indoors, which in itself may indicate characteristics of the offender (2,6,20). Conclusively, although this data did not present any obvious trends in delay in recovery with moving a body to outdoor locations, it may, however, be able to provide information into characteristics of the offender, and ultimately help guide investigators in a targeted approach of identifying the perpetrator (2,6,20).

Research has indicated that offenders are more likely organized killers if they attempt to move a body or destroy evidence (11,36-38). Therefore, it could be said that offenders who moved their victims to outdoor locations (Table 4) may exhibit forensic awareness by trying to conceal the bodies in a less trafficked area (36-38). By comparison, those that left the body at the murder location may be unorganized killers, acting on impulse, exhibiting little forensic awareness (36-38). Both of these can ultimately provide information into their IQ, background and routine activities, i.e., did they target their victims based on their routine activities or were they chosen at random, etc. (2,6, 20,39,40). In many cases, although individuals exhibit more forensic awareness, this may ultimately reveal more information about themselves. Therefore, this study can aid investigators in narrowing their focus for identification of the offender, based on their body disposal location (9,39,40).

4.3. Limitations

The limitations of this study were the sole focus on only North American solved cases, the lack of information provided for each victim and the overall under-representation of bodies disposed of in water.

5. CONCLUSION

Although the findings in this study are preliminary, the general trends that were identified were, an increase in body recovery delay (>48 hours) with victims discovered in outdoor locations, particularly outdoor closed and water locations, and the discovery of bodies within 24 hours being located in victim's residences. These findings and associated evidentiary implications indicate that cases found within 48 hours and above are most important for recovery of evidence and preventing degradation, based on limitations associated with outdoor and water recoveries (2,11,27-29,33-34). Ultimately these findings can be applied in real-world scenarios by providing information to law enforcement on time-critical periods for evidence recovery (<48 hours) and provide focus for the distribution of resources, the type of offender, and also reinforce the importance of the first 48 hours in body recovery, with reference to evidence collection and solvability of cases (2,11,27-29,33-34).

Future research would include the application of these variables to unsolved cases. For example, due to the under-representation of water cases (Table 2), it may be useful for police departments to investigate unsolved cases to identify if any are water-related, and if so, are they unsolved due to the absence of the body, or the forensic implications surrounding evidence collection in relation to the length of time they were immersed in

water. In addition, for unsolved or “cold” cases, it would be beneficial to form cold case units with specialists in forensic science and criminology to share expertise (1). These findings overall highlight the importance of collaboration and incorporation of experts in criminology and forensic science in the first 48 hours of an investigation to optimize body recovery, evidence collection and therefore, finding leads and apprehending offenders.

In addition, it would be beneficial to undertake more detailed investigations into solved cases. Specifically, identifying the time lapse between each murder and when the case was solved (i.e., the decade of activity) to detect critical issues in solvability. For example, were cases that took longer to solve due to the inability to locate a body or, was it due to lack of evidence and forensic advancements at the time. Lastly, an investigation into the sequencing of MOs of solved cases may provide more information as to whether a change in MO was the reason the offender was eventually prosecuted, or if there are any other notable trends. Overall, this study can assist law enforcement on the importance of the proper distribution of resources, particularly, a focus on critical locations to investigate in missing person cases that are associated with delayed body recovery, such as water disposal locations. This is important for investigations as evidence collection and preservation is critical for solvability of cases.

6. REFERENCES

1. Allsop C. Cold Case Homicide Reviews. In: Hoboken, NJ, USA: John Wiley & Sons, Inc; 2017. p. 566-77
2. Reale K, Beauregard E. Body Recovery After the “First 48”: Implications for Sexual Homicide Investigations. Homicide Studies. 2018:1088767918795209.
3. Brown KM, Keppel RD. Child Abduction Murder: The Impact of Forensic Evidence on Solvability. Journal of Forensic Sciences. 2012;57(2):353-63.
4. Mouzos J, Muller D. Solvability factors of homicide in Australia: An exploratory analysis. Canberra: Australian Institute of Criminology. 2001;(216):1-6.
5. Brown KM, Keppel RD. Child Abduction Murder: An Analysis of the Effect of Time and Distance Separation Between Murder Incident Sites on Solvability. Journal of Forensic Sciences. 2007;52(1):137-45.
6. Beauregard E, Martineau M. No body, no crime? The role of forensic awareness
7. in avoiding police detection in cases of sexual homicide. Journal of Criminal Justice. 2014;42(2):213-20.
8. DiBiase TA. No-Body Homicide Cases: A Practical Guide to Investigating, Prosecuting, and Winning Cases When the Victim is Missing. ProtoView. 2015;2(7).
9. Godwin M. VICTIM TARGET NETWORKS AS SOLVABILITY FACTORS IN SERIAL MURDER. Social Behaviour and Personality: an international journal. 1998;26(1):75-83.
10. Ferguson C, Pooley K. Comparing solved and unsolved no-body homicides in Australia: An exploratory analysis. Homicide Studies. 2019:1088767919852381.

11. Cockle DL, Bell LS. Human decomposition and the reliability of a 'Universal' model for post mortem interval estimations. Forensic Science International. 2015;253:136.e1,136.e9.
12. 11. Lee HC, Palmbach T, Miller MT. Henry Lee's crime scene handbook. Academic Press; 2001 Jul 25.
13. Ferguson C. Staged homicides: An examination of common features of faked burglaries, suicides, accidents and car accidents. Journal of Police and Criminal Psychology. 2015 Sep 1;30(3):139-57.
14. Rutty GN, Hopwood A, Tucker V. The effectiveness of protective clothing in the reduction of potential DNA contamination of the scene of crime. International journal of legal medicine. 2003 Jun 1;117(3):170-4.
15. Addington LA. Using NIBRS murder data to evaluate clearance predictors: A research note. Homicide Studies. 2006;10:140-52.
16. Litwin KJ, Xu Y. The dynamic nature of homicide clearances: A multilevel model comparison of three time periods. Homicide Studies. 2007 May;11(2):94-114.
17. Mouzos J, Muller D. Solvability factors of homicide in Australia: An exploratory analysis. Canberra: Australian Institute of Criminology; 2001 Oct 1.
18. Wellford CF, Cronin JM, Brandl S, Bynum T, Eversen T, Galeria S. An Analysis of Variables Affecting the Clearance of Homicides: A Multistate Study. Washington, DC: Justice Research and Statistics Association; 1999 Oct.
19. Litwin KJ. A multilevel multivariate analysis of factors affecting homicide clearances. Journal of Research in Crime and Delinquency. 2004 Nov;41(4):327-51.
20. Beauregard E, Bouchard M. Cleaning up your act: Forensic awareness as a detection avoidance strategy. Journal of Criminal Justice. 2010 Nov 1;38(6):1160-6.

21. Sea J, Beauregard E, Martineau M. A cross-cultural comparison of Canadian and Korean sexual homicide. International journal of offender therapy and comparative criminology. 2019 Mar 2:0306624X19834408.
22. Rhineberger-Dunn G, Briggs SJ, Rader NE. The CSI Effect, DNA Discourse, and Popular Crime Dramas. Social Science Quarterly. 2017 Jun;98(2):532-47.
23. Heinrick J. Everyone's an expert: The CSI effect's negative impact on juries. The Triple Helix. 2006;3(1):59-61.
24. Lawson TF. Before the verdict and beyond the verdict: The CSI infection within modern criminal jury trials. Loy. U. Chi. LJ. 2009;41:119.
25. Maeder EM, Corbett R. Beyond frequency: Perceived realism and the CSI effect. Canadian Journal of Criminology and Criminal Justice. 2015 Jan;57(1):83-114.
26. Baskin DR, Sommers IB. Crime-show-viewing habits and public attitudes toward forensic evidence: The "CSI effect" revisited. Justice System Journal. 2010 Jan 1;31(1):97-113.
27. Nolan A, Mead RJ, Maker G, Speers SJ. A review of the biochemical products produced during mammalian decomposition with the purpose of determining the post-mortem interval. Australian Journal of Forensic Sciences. 2019:1-12.
28. Cockle DL, Bell LS. Human decomposition and the reliability of a 'Universal' model for post mortem interval estimations. Forensic science international. 2015 Aug 1;253:136-e1.
29. Ritchie GT. A comparison of human decomposition in an indoor and an outdoor environment.

30. Anderson GS. Comparison of decomposition rates and faunal colonization of carrion in indoor and outdoor environments. Journal of Forensic sciences. 2011 Jan 1;56(1):136-42.
31. Schroeder H, Klotzbach H, Oesterhelweg L, Püschel K. Larder beetles (Coleoptera, Dermestidae) as an accelerating factor for decomposition of a human corpse. Forensic Science International. 2002 Jul 17;127(3):231-6.
32. Komar DA. Decay rates in a cold climate region: a review of cases involving advanced decomposition from the Medical Examiner's Office in Edmonton, Alberta. Journal of Forensic Science. 1998 Jan 1;43(1):57-61.
33. Micozzi MS. Experimental study of postmortem change under field conditions: effects of freezing, thawing, and mechanical injury. Journal of Forensic Science. 1986 Jul 1;31(3):953-61.
34. Borde YM, Tonnany MB, Champod C. A study on the effects of immersion in river water and seawater on blood, saliva, and sperm placed on objects mimicking crime scene exhibits. Canadian Society of Forensic Science Journal. 2008 Jan 1;41(3):149-63.
35. Beckwith S, Murakami J, Chapman B. The persistence of semen on cotton fabric in various water environments. Australian Journal of Forensic Sciences. 2018 Oct 2:1-0.
36. Lee SJ, Park J. Body Transportation after Homicides: Offender and Offense Characteristics. Journal of forensic sciences. 2018 Dec 1.
37. Skinner M, Lazenby RA. Found! Human remains: A field manual for the recovery of the recent human skeleton. 1983.

38. Beauregard E, Proulx J. Profiles in the offending process of nonserial sexual murderers. International Journal of Offender Therapy and Comparative Criminology. 2002 Aug;46(4):386-99.
39. Culatta E, Clay-Warner J, Boyle KM, Oshri A. Sexual revictimization: A routine activity theory explanation. Journal of interpersonal violence. 2017 Apr 1:0886260517704962.
40. Chan HC, Heide KM, Beauregard E. What propels sexual murderers: A proposed integrated theory of social learning and routine activities theories. International Journal of Offender Therapy and Comparative Criminology. 2011 Apr;55(2):228-50.