FROZEN JUSTICE: DETECTING AND RECOVERING FIREARMS EVIDENCE AT SNOW SCENES

by

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Dedication

This research is dedicated to the men and women of the United States Armed Forces. May their service and sacrifice never be forgotten.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

AAA……………………………………………………………American Avalanche Association

ACP…………………………………………………………………….Automatic Colt Pistol

AFTE…………………………………………Association of Firearms and Toolmarks Examiners

BFO……………………………………………………………………..Beat Frequency Oscillator

CBC…………………………………………………….…..Cartridges, Bullets, and Casings

CSI…………………………………………………...Crime Scene Investigation/Investigator

DNA…………………………………………………………………Deoxyribonucleic Acid

EMF……………………………………………………………………....Electromagnetic Field

FLIR………………………………………………………………Forward Looking Infrared

GPR……………………………………………………………..Ground Penetrating Radar

LR………………………………………………………………………………….Long Rifle

PPE…………………………………………………...…………Personal Protective Equipment

SW……………………………………………………………………………..Smith & Wesson

TR………………………………………………………………………… Transmitter Receiver

USACID………………………………….....United States Army Criminal Investigation Division

VLF…………………………………………………………………………Very Low Frequency

Abstract

This research project identifies and explores the complexities associated with the detection and recovery of firearms evidence, namely casings, from areas in which snow is prevalent. By reviewing established crime scene processing methodologies, this research sought to determine what, if any, effect snow has on an investigator's ability to find and collect casings when they are concealed underneath a layer of solid precipitation. Casings of eight different sizes were used to establish a mock scene at Fort Drum, New York, where the average annual snowfall regularly exceeds 100 inches. Two different brands of metal detectors were used to recover the casings, a Garrett CSI Pro and a Bounty Hunter Tracker IV. Bench tests performed with both detectors in controlled indoor conditions showed consistent responses to a distance of approximately eight inches across the eight calibers and gauges examined. During the recovery experiment approximately one month after initial deposition, the less expensive detector performed poorly when pitted against the more expensive model. The experiment resulted in the recovery of 48 of 80 casings, a 60% recovery rate. Neither detector was able to locate .22 Long Rifle casings at a depth of approximately 7", indicating a relationship between size of the casing, depth of snow, and strength of the detectors.

Introduction

This research project sought to examine the possible effects snow and ice have on the detection and subsequent recovery of firearms evidence, namely casings, at crime scenes. The objective of this research was to examine two common metal detectors for effectiveness in locating casings of differing sizes, metallic compositions, and calibers under the snow. Firearms evidence, including casings, may contain a wealth of evidence such as ballistic information, fingerprints, and DNA, supporting the extreme value of this class of evidence in criminal investigations (Elwick, Gauthier, Rink, Cropper, & Kavlick, 2022).

Metal detectors have been used for over a hundred years by hobbyists and in military, security, and criminal investigation capacities (Nelson, 2004). One application has been the detection of buried landmines which pose a threat to civilian populations living in the vicinity of current or former warzones. Takahasi, Preetz, and Igel (2010) highlight the suitability of the common metal detector to the task of landmine detection due to low costs, simple operation, and overall reliability of the method. In the post-9/11 era, walk-through metal detectors are commonplace in airports, government buildings, and even tourist spaces or event venues. All of the benefits highlighted by Takashi et al. regarding the merits of metal detectors for landmine detection can be applied to their use by CSIs for the detection of metallic evidence, including casings, bullets, whole firearms, or other metallic weapons.

The experiment was conceptualized to involve the deposition of eight sizes of casings at Fort Drum, a military installation in upstate New York located east of Lake Ontario and just 30 miles from the Canadian border. Baseline measurements were obtained via bench tests for both types of detectors prior to searching the experiment scene for the casings. By comparing the number of casings of each size recovered per detector to the accumulated snow (in inches), a relationship between the device used and rate of recovery was determined. Results from this research may shape the way crime scene investigators (CSIs) approach future evidence recovery efforts at snow scenes worldwide.

Background

Shooting incidents remain pervasive in the United States, where gun ownership is enshrined in the Second Amendment to the Constitution. Americans regularly exercise their right to bear arms, with surveys showing more than four in ten Americans live in a household where at least one gun is present (Van Green, 2021). When guns are used in the commission of a crime, it often falls to a trained CSI to recover the valuable evidence left behind. This may include the firearm itself, casings which are ejected when a gun is fired, and bullets extracted from a target surface.

The first use of forensic firearm identification was reported in London, England in 1835 when Henry Goddard identified the mold mark on a lead ball involved in a shooting (Hamby & Thorpe, 1999). In the years since Goddard's identification of the lead ball mark, forensic firearms identification has evolved into a complex science involving sophisticated microscopes, test ranges, and modern methods for associating firearms and related evidence to individuals. Completion of such scientific analyses is contingent upon the successful detection and recovery of the evidence on scene.

Crime scene investigation texts have thoroughly documented the best methods for recovering this class of evidence. Texts such as those by Gardner (2012), Shaler (2012), Fish, Miller, Wallace and Braswell (2014), and Dutelle (2016) outline step-by-step evidence collection methods the CSI should employ on scene. Generally, these procedures involve systematic processes which vary based on factors including the nature of the scene, lighting conditions, environmental factors, and available manpower. Once evidence has been located, thorough documentation in the form of notes, photographs, and sketches will be completed before the object is collected. Dutelle (2016) recommends collecting bullets or cartridge cases in a sealed pillbox or plastic vial for submission to the crime laboratory.

What these texts tend to omit are specific procedural instructions for the detection and subsequent collection of firearms evidence at snow scenes. Many references to snow in the context of crime scene investigations relate only to snow prints (footwear or tire impressions). I theorize a relatively simple geophysical search tool, the metal detector, can be used to locate this type of concealed evidence. Though not the subject of this research, other geophysical search tools merit discussion due to the amount of emerging literature concerning their use for forensic applications. These include Ground Penetrating Radar (GPR) and Forward Looking Infrared (FLIR).

Daniels (2010) discussed GPR at length, highlighting two of the key benefits of the system: GPR produces a three-dimensional rendering of the subsurface, and GPR responds to both metallic and non-metallic objects. Forensic applications of GPR technology include the detection of metal snares frequently used by wildlife poachers (Borrion, Amiri, Delpech, & Lemieux, 2019). Perhaps the largest detractor to the use of GPR systems by CSIs is the cost, as an entry-level system starts around $14,000, likely outside of the budget of smaller law enforcement agencies.

FLIR is another search tool, which detects infrared radiation from a heat source. Research by Kerampran, Gajewski, and Sielicki (2020) documented temperatures associated with the firing of several types of ammunition and received results between 25°C and 90°C (77-194°F). However, in the context of a snow scene, this technology would likely not be beneficial, as the ambient air temperatures associated with snow scenes would rapidly cool the casing and thus not allow for its detection by the FLIR system.

Literature

Benefits of metal detector deployment by CSI teams have also been documented, though without reference to the effects of snow (Rezos, Schultz, Murdock, & Smith, 2009) (Chan, 2020). Contemporary references to metal detectors in the literature focus primarily on applications such as archaeology and simple detection of buried metallic objects (Connor & Scott, 1998). This research was partially inspired by such archaeological applications, notably their reported use by Rickey (1958) in his exploration of the battlefields of Little Bighorn, and by Parrington, Schenck, and Thibaut (1984), who documented aspects of the Revolutionary War campsite at Valley Forge. Their detection of archaeological artifacts, from lead musket balls to spoons, suggests the viability of detectors for forensic applications in which locating metallic items, such as casings, is vitally important.

While metal detector literature is sparse with regards to their operation by CSIs, France et al. (1992) documented the benefits of the metal detector in their work on the detection of clandestine graves, noting detectors are non-intrusive and minimally invasive, though with limited depth detection. Larson, Vass, and Wise (2011) discuss clandestine graves at length, noting that search efforts for the location of these graves are frequently conducted by law enforcement officials in conjunction with anthropologists or archaeologists from local universities, and focused on surface level investigations.

Perhaps more pertinent to the aims of this project, Rezos et al. (2009) demonstrated the successful use of a metal detector to locate buried firearms and weapons of various calibers and sizes using geophysical search techniques. Rezos' team deposited 16 firearms, including 13 handguns, a rifle, and two shotguns in a controlled area of the Orange County Sheriff's Office facilities in Orlando, Florida. Scrap metal, including copper, aluminum, and iron, were also used, as were additional weapon-type objects, such as a machete, brass knuckles, and a hammer. Their team utilized a Fisher M-97 basic all-metal detector featuring an 11 inch "Double-D" waterproof search coil and successfully located all of the evidence included in their experiment design, though some of the smaller firearms, such as a Derringer pistol, produced strong audible responses only at a depth of 10-15cm (approximately 3.9 to 5.9 inches).

Nielsen (2003) highlighted some of the generalizations that can be made regarding the depth capabilities of metal detectors. He noted under normal conditions a 9mm or .38 caliber bullet could realistically be detected to a depth of six to nine inches. Regarding the size of the search coil, Nielsen stated the detection coverage is approximately equal to the diameter of the search coil. Detection patterns are conical in nature, indicating coverage decreases with depth. This presents a greater detection challenge for smaller evidence items such as casings as opposed to larger items such as whole firearms.

Casings as Evidence

Cartridge casings and shotshells contain a variety of useful forensic evidence encompassing both class and individual characteristics. Casework conducted pertaining to forensic firearms identification is based upon the theory that casings can be positively identified to the firearm which fired them (Castro, Norris, Setume, & Hamby, 2014). For the past hundred years, forensic firearms examiners have largely conducted this task with the use of comparison microscopes. Unique marks are applied to the casing when fired and are known as striations. The leading body for this scientific endeavor in the United States is the Association of Firearms and

Toolmark Examiners (AFTE). AFTE literature describes the process as a blend between art and science, whereby the examiner's ability to recognize patterns in striations is coupled with scientific testing designed to reproduce striations and confirm their intuition.

AFTE offers four possible conclusions for examinations: identification, inconclusive, elimination, or unsuitable. Identifications are made when:

Agreement of a combination of individual characteristics and all discernable class characteristics where the extent of agreement exceeds that which can occur in comparison of tool marks made by different tools and is consistent with agreement demonstrated by toolmarks known to have been produced by the same tool. (AFTE Journal, 1992)

Per the AFTE, an inconclusive result is indicated by the agreement of all discernible class characteristics, yet there are insufficient individual characteristics for either an identification or an elimination. Eliminations are made when there exists a "significant disagreement" between class and/or individual characteristics, and unsuitable indicates the item was unsuitable for testing (AFTE, 1992).

The rise in the strength of deoxyribonucleic acid (DNA) testing has made the recovery of DNA profiles possible from fired cartridge cases (Johnson, 2019). Mawlood, Denanny, Watson, and Pickard (2019) reported success in obtaining sufficient DNA for typing after cartridge cases were exposed to the intense heat of the firing process. Research has also demonstrated the ability of latent prints, or at least partial patterns thereof, to survive the firing process (Girelli et al., 2018). Further complementing the conditions present in this research, a study published in the Egyptian Journal of Forensic Science detailed to the ability to develop latent fingerprints on surfaces exposed to fresh and sea water (Madkour, Sheta, El Dine, Elwakeen, & AbdAllah, 2017).

Recovering latent prints or DNA profiles can strengthen the overall evidence available in the investigation. Two qualities, uniqueness and permanence, have long elevated latent fingerprints as a strong class of evidence, allowing a latent print examiner to positively associate a fingermark to a single person. Bonsu, Higgins, and Austin (2020) reviewed the current practices associated with recovery of epithelial (touch) DNA from metal surfaces. They highlighted the success of Fan et al. (2017) in recovering touch DNA from different parts of guns and what they referred to as CBCs (cartridges, bullets, and casings).

Snow

Snow is a form of precipitation and represents one of the environmental conditions CSIs may encounter. Accumulation of snow obscures the ground surface, concealing valuable evidence. Jiusto and Weickmann (1973) provided a comprehensive description of the formation of snowflakes, and further describe the many varieties of snowfall. They state snow crystals grow by diffusion of water vapor followed by crystal riming and aggregation. Upstate New York is susceptible to a special type of snowfall, that of lake effect snow. These snow bands develop when polar continental or artic air masses cross the warmer waters of the lake below (Niziol, Snyder, & Waldstreicher, 1995). The period from August to mid-March is described by Niziol et al. as the unstable season, when the heat and moisture from the lake below affects the air mass above, resulting in increased cloudiness and precipitation.

Recent advances in the fields of hydrology and cryospheric sciences have led to new internationally accepted methods for documenting snow. Snow on the ground is regularly near its melting temperature and, as such, is in a continuous state of flux, commonly referred to as metamorphism (Fierz et al., 2009). The measurement and classification of the physical properties of snow is documented within the following categories: microstructure, grain shape, grain size, snow density, snow hardness, liquid water content, snow temperature, impurities, and layer thickness (Fierz et al., 2009).

A number of organizations, including the American Avalanche Association (AAA) and the U.S. Forest Service, a division of the U.S. Department of Agriculture, collaborated to produce a reference guide entitled *Snow, Weather, and Avalanches: Observation Guidelines for Avalanche Programs in the United States* (2022), commonly known as SWAG. While snow accumulation associated with avalanches is outside the scope of this research, the text outlines with great detail the many variables associated with the proper documentation of snow. Of interest, their guidelines for precipitation type include the categories of: no precipitation, rain, snow, mixed rain/snow, graupel/hail, and freezing rain (American Avalanche Association, 2022). Graupel and hail are somewhat related, with graupel often referred to as “soft hail” and both representing a form of water ice precipitation. Each of these precipitation types presents unique challenges for scene investigations.

Safety Considerations at Snow Scenes

CSIs operating at snow scenes must be adequately trained and prepared in order to successfully endure potentially lengthy investigations in temperatures at or below freezing, and with various types of precipitation and wind conditions. Cold stress is an environmental or personal condition that tends to remove heat from the body and decrease body temperature (U.S. Army, 2005). Mitigation of cold stress and prevention of common cold-weather related injuries, such as hypothermia and frostbite, can be accomplished by following the Army's acronym COLD, as it relates to dressing for cold weather operations (U.S. Army, 2005):

- Keep it Clean
- Avoid Overheating
- Wear it Loose and in Layers
- Keep it Dry

Without adequate protection for the appendages, such as warm gloves, the CSI is at increased risk for frostbite. Glove liners of a warm material such as wool can be worn beneath disposable nitrile or latex gloves to prevent evidence contamination on scene. Table 1, published by the U.S. Army (2005) demonstrates the amount of time it takes human finger-skin to reach freezing when touching different materials:

Material Temperature	Aluminum	Steel	Stone
32 °F	43 seconds	>100 seconds	>100 seconds
23 °F	15 seconds	50 seconds	>100 seconds
14 °F	5 seconds	15 seconds	62 seconds
5 °F	2 seconds	5 seconds	20 seconds
–4 °F	1 second	2 seconds	7 seconds
–13 °F	<1 second	<1 second	4 seconds

Table 1. *Time in seconds to reach a finger-skin temperature of 32° F*

Principles of Metal Detector Operation

Electromagnetic fields (EMF) transmitted from the search coil of a metal detector are capable of penetrating many types of substrates, such as soil, rock, air, and water (Rezos et al., 2009). Metals coming into contact with the detector's EMF cause eddy currents and electromagnetic distortion, resulting in a loss of power in the EMF generated by the detector (Nielsen, 2003). The detector senses this loss of power and indicates to the operator the presence of metal (see Figure 1). Nielsen (2003) described five different types of circuitries employed in metal detectors: beat frequency oscillator (BFO), transmitter receiver (TR), very low frequency (VLF), automatic VLF, and pulse induction.

An important concept in the selection of a detector for crime scene work is the operating frequency. These frequencies are typically measured in kilohertz (kHz) and correspond to the number of electromagnetic waves emitted by the detector per second. Many hobbyist metal detectors use an operating frequency of between six to eight kHz, whereas professional detectors use higher frequencies such as 15 or 18 kHz. Portable metal detectors like those used in this research typically operate on internal battery power. The Tracker IV and CSI Pro are both powered by two 9-volt batteries housed in a battery compartment on the control module (see Figure 2).

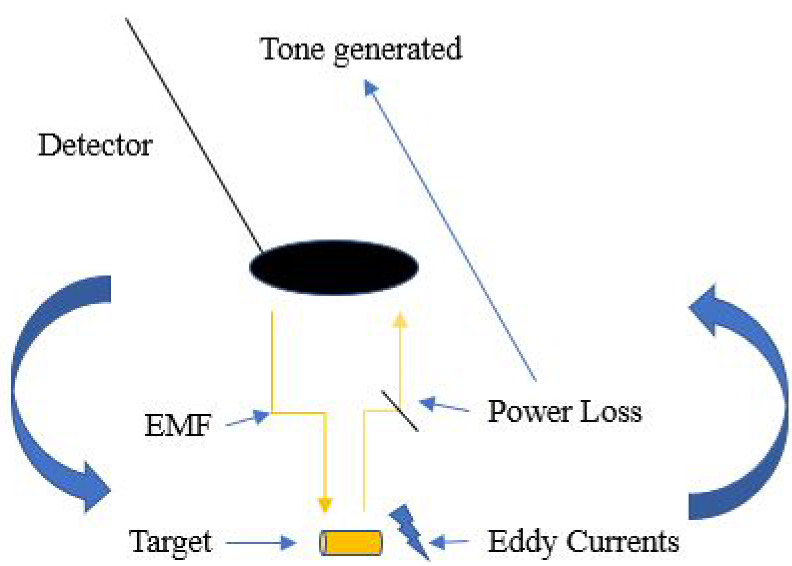

Figure 1. *Metal detector operation*

Other important features of portable metal detectors include sensitivity settings, ground balance, and notch discrimination settings. Sensitivity refers to the ability of the detector to find smaller pieces of metal. In the case of the CSI Pro, the detector includes eight levels of sensitivity and the manufacturer recommends using higher sensitivity for small or deep targets, and low sensitivity for areas where the detector behaves erratically due to excess trash or soil mineralization (Garrett Electronics Inc., 2012).

Ground balance allows the user to establish a baseline setting for the detector based upon indications received from soil in the search area. In essence it is a way to “zero out” the detector to eliminate excess noise from the substrate. Finally, notch discrimination is an internal setting which the user can toggle to eliminate responses from unwanted objects, examples of which might include pop-tabs or aluminum foil. This feature is useful when the composition of the target items are known, such as the steel or brass casings included in this research.

Metal detector retailers generally offer a range of products designed and marketed for varying purposes. Bounty Hunter, the manufacturer of the Tracker IV used in this research, offers the following categories of handheld portable metal detectors: Starter, Intermediate, Advanced, Serious, Pro, Discovery, and Pioneer. Differences between these models usually involves the addition of features designed for ease of use as the consumer ascends the different levels. For example, the starter level detectors feature analog controls and a smaller, 6” search coil, with a retail price beginning around $99. The advanced “time ranger” model features a digital display, target discrimination, digital identification and depth readout, and a larger 8” waterproof search coil, offered at $649. Of note, additional accessories and specialized detectors are marketed to accompany the main unit. An example of this is the Garrett Pro-Pointer, which is a model of “pinpoint” detector designed to narrow the search area once a metallic object has been detected by the larger detector. The Pro-Pointer retails for approximately $129 and was not assessed as a part of this research.

Many purveyors of detecting equipment sell search coils in varying sizes that are easily swapped out by disconnecting the coil cable from the control module and dismounting the search coil from the detector shaft, allowing the user to select a coil best suited for their intended purpose. A waterproof search coil is one designed for use in wet conditions and even allows for the entire coil to be submersed, facilitating detection in shallow bodies of water. Such waterproof coils are also suitable for use at snow scenes as there is little risk for equipment malfunction were the coil to become wet from snow.

Figure 2. *Major components of a common metal detector*

Methods and Materials

Materials for this research included ten casings of eight different calibers/gauges, for a total of 80: .22 Long Rifle (LR), 9mm, .40 Smith and Wesson (S&W), .45 Automatic Colt Pistol (ACP), 5.56mm, .30-30 Winchester, 12 Gauge Shotshell, and .38 Special (see Table 1). These calibers were selected due to their popularity in the United States, with .22 LR representing the most ammunition sold by volume, and 9mm representing the most popular handgun caliber (Moscary, Johnson, Wallace, & Kopel, 2020). The casings were received for this project in their expended state and prepared for distribution in the experiment area. The brands and specifications for the ammunition used are reflected in Table 2.

Brand	**Metal**	**Caliber**	**Length**	**Width (Base)**	**Weight (Oz)**
American Eagle	Brass	.45 Auto	22mm	12mm	0.205
Federal Ammunition Auto Match	Brass	.22 LR	15mm	6mm	0.025
Federal Ammunition Target Load	Steel	12 Gauge	68mm	22mm	0.28
Federal American Eagle	Brass	5.56mm	44mm	10mm	0.225
Remington Arms Company	Brass	9mm Luger	18mm	10mm	0.145
Remington Arms Company	Brass	.40 SW	20mm	10mm	0.16
Hornady	Brass	.30-30	51mm	12mm	0.32
Winchester	Nickel Plated Brass	.38 Special	28mm	10mm	0.155

Table 2. *Ammunition Specifications*

Data obtained from the Bureau of Alcohol, Tobacco, and Firearms (ATF) highlighted the calibers most commonly traced for the state of New York in 2021 (see Figure 3). ATF's National Tracing Center (NTC) facilitates requests by ATF or other law enforcement agencies to track a firearm, via its serial number, from point of manufacture through the first retail sale of the firearm. This trace information could help to identify a suspect in an investigation, assuming the firearm was still in possession of the individual who first purchased it in a retail setting. Reviewing the trace data for New York revealed 9mm was the most commonly traced caliber by almost four times over the second place .22 caliber.

Two different metal detectors, a Garrett CSI Pro and a Bounty Hunter Tracker IV, were examined to compare the effectiveness of high-end and low-end models respectively. For the context of this project, any portable detector marketed for $500 or more was considered as "high-end", with any detector below that price range in the "low-end" category. While the purpose of both products is the same, detection of metal objects, the features between the two models vary greatly. Both systems are powered by two 9V batteries, and both are marketed with waterproof coils. The CSI Pro features a more complex control module, including a digital display with multiple features, including target identification and depth indication (see Figures 4 and 5).

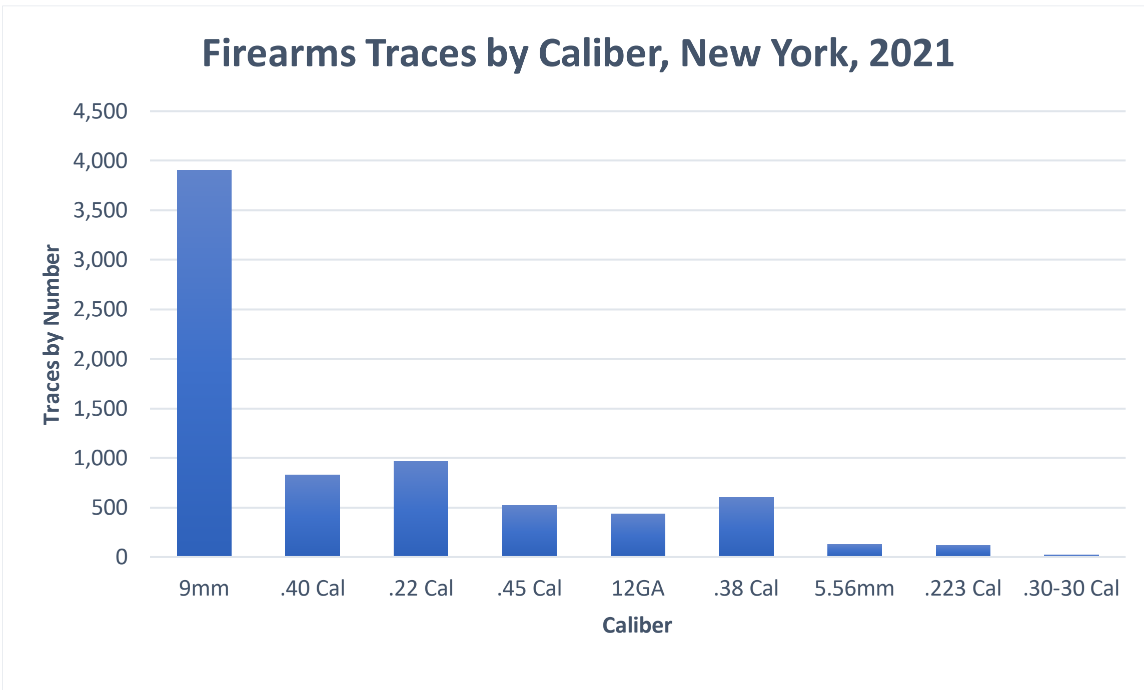

Figure 3. *Firearms traces by caliber for New York, 2021*

The CSI Pro's target indicator provides a numerical output when a metal object is detected, with brass generally resulting in an indication from 40 to 80[1]. This allows the user to easily discriminate from other items which might not be the target of the search, such as iron debris. The CSI Pro also has a pinpoint feature, which results in a stronger tone when the

[1] On the Garrett CSI Pro, the Target ID number ranges from 10 to 90 and represents distinct types of metals. For more information see Figure 4.

pinpoint button is depressed and the coil is directly over the target object. This provides a smaller search area as opposed to the Tracker IV, which emits a tone when passed over a metallic object and leaves the user to search the entire area of the corresponding pass. The digital display of the CSI Pro's control module is reflected in Figure 4 and the Tracker IV's analog control module is reflected in Figure 5.

Figure 4. *Garrett CSI Pro Control Module Display*

Figure 5. *Bounty Hunter Tracker IV Control Module Display*

Additional materials for the experiment included sections of rebar, a wooden framed sifter with metal mesh, heat lamps, trowel, sledgehammer, paint, marking tape, collection envelopes, and five-gallon buckets. The experiment area was established as a 20’ by 80’ grid, outlined with orange spray paint, and with rebar used to mark the perimeter of the area so as to visualize the experiment site once significant snowfall had occurred. High visibility orange marking tape was affixed to the rebar for safety purposes.

The researcher selected a site behind the Northeast Field Office which was normally undisturbed so as to minimize the risk for disruption to the experiment. Security of the site was ensured both by the location on a military base and by the position in the rear of the CID facility. Each subsection was established as 10’ by 20’, for a total of eight sections. A disinterested CID Agent assigned to the Northeast Field Office dispersed ten casings of the same caliber into one of the eight grids. The location of each caliber within the grids was unknown to the researcher prior to the collection experiment.

Bench tests were conducted with both detectors which involved removing the coil from the shaft of the detector, and resting the coil vertically (see Figure 6). The casings were then passed in front of the coil at varying distances, from one to eight inches, to test for a response. Eight inches was the maximum distance to return a response (see Tables 3 and 4). This procedure was detailed in the user manual for the Garrett CSI Pro (Garrett Electronics Inc., 2012).

The casings were deposited in the research area by the disinterested CID Agent on 15 December 2022 at surface level, and the collection experiment was performed on 19 January 2023 at a time when snow accumulation at the experiment site averaged approximately 7”.

Bounty Hunter Tracker IV

	.22 LR	9mm	.40 S&W	.45 ACP	5.56mm	.30-30	12ga	.38 SPL
1"	Response	Response	Response	Response	Response	Response	Response	Response
2"	Response	Response	Response	Response	Response	Response	Response	Response
3"	No Response	Response	Response	Response	Response	Response	Response	Response
4"	No Response	No Response	Response	Response	Response	Response	Response	Response
5"	No Response	No Response	No Response	No Response	Response	Response	No Response	Response
6"	No Response	No Response	No Response	No Response	Response	Response	No Response	No Response
7"	No Response	No Response	No Response	No Response	Response	Response	No Response	No Response
8"	No Response	No Response	No Response	No Response	No Response	No Response	No Response	No Response

Key: Response No Response

Table 3. *Bounty Hunter Tracker IV Bench Test Results*

Garrett CSI Pro

	.22 LR	9mm	.40 S&W	.45 ACP	5.56mm	.30-30	12ga	.38 SPL
1"	46	62	60	65	60	65	20	61
2"	48	62	61	65	60	63	20	58
3"	46	62	60	65	62	63	48	60
4"		59	59	65	62	66	70	60
5"		61	53	61	59	61	59	48
6"		43	65	62	61	63	59	
7"			53	69	53	62	58	
8"				63			53	

Key: Response + Target ID # No Response

Table 4. Garrett CSI Pro Bench Test Results with target ID

Weather data was obtained for the experiment window from the National Weather Service (NWS), a division of the National Oceanic and Atmospheric Administration (NOAA), and documented in Table 5 (U.S. Department of Commerce, n.d.). The daily high and low temperatures as well as the amount of new snow plus snow depth were reviewed indicating that

Figure 6. *Bench test overview*

Date	Max Temp (°F)	Min Temp (°F)	Average Temp	New Snow (")	Snow Depth (")
12/15/2022	24	11	17.5	0	1
12/16/2022	37	18	27.5	4	4
12/17/2022	33	31	32	0.5	4
12/18/2022	34	27	30.5	7	11
12/19/2022	32	16	24	3	12
12/20/2022	31	22	26.5	0.5	11
12/21/2022	28	21	24.5	0	10
12/22/2022	34	18	26	0	9
12/23/2022	46	28	37	0	1
12/24/2022	43	**5**	24	8	8
12/25/2022	14	6	10	6	6
12/26/2022	22	6	14	17	17
12/27/2022	23	16	19.5	18	19
12/28/2022	27	21	24	T	20
12/29/2022	41	27	34	0	14

12/30/2022	50	40	45	0	4
12/31/2022	54	36	45	0	2
1/1/2023	50	33	41.5	0	0
1/2/2023	38	34	36	0	0
1/3/2023	39	27	33	0	0
1/4/2023	37	29	33	0	0
1/5/2023	39	34	36.5	0	0
1/6/2023	41	29	35	0	0
1/7/2023	37	29	33	0	0
1/8/2023	30	13	21.5	0	0
1/9/2023	27	20	23.5	0	0
1/10/2023	33	20	26.5	0	0
1/11/2023	23	10	16.5	0	0
1/12/2023	37	11	24	0	0
1/13/2023	41	29	35	2	2
1/14/2023	29	12	20.5	2.5	5
1/15/2023	17	4	10.5	0	5
1/16/2023	19	6	12.5	0	5
1/17/2023	25	6	15.5	0	4
1/18/2023	41	18	29.5	0	1
1/19/2023	36	26	31	0	0

Table 5. *Daily weather data for Watertown, NY*

there were five days during the experiment window where the temperature never dipped below freezing (32° F). Further, 68.5 inches of new snow fell during the period between casing deposition and recovery.

A systematic search pattern, the grid search, was used beginning with the Tracker IV and followed by the CSI Pro (Gardner, 2012). Grid search procedures involve dividing the search area into two sets of lanes, with the second set at 90° to the first. This search technique was selected to provide maximum overlap with the normal horizontal swinging motions of the detector. When a tone was heard through the headphones plugged into the detector, a yellow plastic evidence marker was placed on the ground to mark locations for subsequent excavation.

Snow was excavated into the five-gallon buckets using a plastic trowel and sifted under heat lamps to ensure no casings were missed (see Figure 7). The buckets were not labeled as only one section of the grid was processed at a given time. This procedure is similar to the established procedures for processing of buried remains as outlined by Maloney (2017). The processing is sequential and methodical to both ensure proper documentation and to establish chain of custody for any items of evidence detected, be they human remains, a casing, or otherwise. One complexity associated with the excavation of a snow scene is the variation in snowpack at different depths. In areas where casings were detected, the top two to four inches of snow could generally be removed with the trowel alone. The bottom two to three inches was often a solid layer of ice, likely due to the thawing and refreezing as a consequence of the temperature fluctuations over the experiment period. Occasionally the casing could be visualized, through the ice, necessitating the breaking of the ice before the casing could be collected (see Figure 8).

This was accomplished both with the plastic trowel and also with a sledgehammer, which was used to loosen the ice surrounding the casing, exercising care not to damage the casing itself. Once sufficient snow or ice was removed, the casing was photographed in situ, with and without scale, with a Nikon D5600 digital camera (see Figure 9). Casings were then collected with a gloved hand and deposited in a clean paper envelope. Paper was used over plastic due to the wet nature of the casings. A second re-check of each grid was completed with the CSI Pro before moving on to process the next grid. On second re-check, when no further tones were detected, the researcher considered the search of that grid complete.

Figure 7. *Sifter setup under heat lamps*

Figure 8. *Casing before recovery*

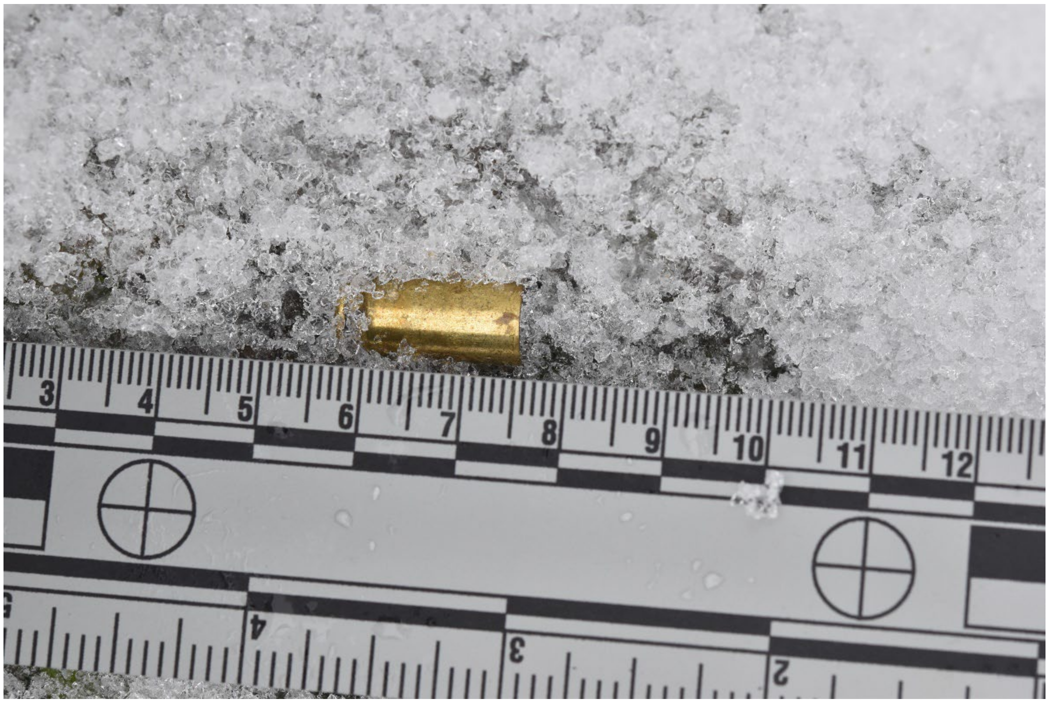

Figure 9. *In situ photography with scale*

Overall, the collection experiment spanned approximately 12 hours over two days (19-20 January 2023). Search efforts on the first day were halted when darkness set in, an additional factor field CSIs may encounter in real-world investigations. The researcher opted to return at daybreak on the second day, as the addition of supplemental lighting to the experiment area was not viable.

Data Analysis and Interpretation

Garrett's CSI Pro outperformed the Tracker IV (95.83% of casings detected to 4.16%), having detected 46 of the 48 casings ultimately recovered (see Table 6). The Tracker IV was only able to detect two casings, both being .30-30 Winchester, the largest casing included in the experiment by weight. The CSI Pro's advanced features, including pinpoint location ability, detected casings of every caliber with the exception of .22 Long Rifle, the small size of which proved too difficult to detect for either system. The CSI Pro's operating frequency of 15 kHz penetrated the snow and ice with ease, returning readings for 46 casings. The Tracker IV's 6.6 kHz frequency struggled, returning only two readings.

Through sequential processing, the researcher was able to ascertain the location of the eight varieties of casings included in the experiment, though the location of the .22 LR grid was ascertained only via the process of elimination (see Figure 10). No .22 LR cases were detected or collected.

A chi-squared (χ^2) test was conducted based upon the number of casings recovered and unrecovered for each caliber/gauge (see Table 7). The resulting χ^2 value was 28.333, with a P-value of <0.001 at seven degrees of freedom. Consultation with the χ^2 chart available in Lucy (2013) indicates the χ^2 value of 28.333 at seven degrees of freedom is significant beyond 1%. With the understanding a difference existed between the calibers and gauges, a correlation test was conducted utilizing GraphPad Prism to assess the relationship between the number of casings recovered and the weight of the casings in ounces.

Detector	Caliber	Time	Depth
CSI Pro	5.56mm	1635	6"
CSI Pro	5.56mm	1646	6"
CSI Pro	5.56mm	900	5"
CSI Pro	5.56mm	1132	6"
CSI Pro	5.56mm	1138	5.5"
CSI Pro	5.56mm	1142	5.5"
CSI Pro	5.56mm	1145	6"
CSI Pro	.30-30	1424	5.5"
CSI Pro	.30-30	1425	6"
CSI Pro	.30-30	1428	6.5"
CSI Pro	.30-30	1432	6"
CSI Pro	.30-30	1434	6"
CSI Pro	.30-30	1440	6"
CSI Pro	.30-30	1443	6"

TKIV	.30-30	927	6"
TKIV	.30-30	949	5"
CSI Pro	.38 SPL	1239	6"
CSI Pro	.38 SPL	1250	5.5"
CSI Pro	.38 SPL	1258	5"
CSI Pro	.38 SPL	1304	6"
CSI Pro	.38 SPL	1316	6"
CSI Pro	.38 SPL	1321	5.5"
CSI Pro	.38 SPL	1323	5"
CSI Pro	.38 SPL	1325	5"
CSI Pro	.40 SW	1503	4"
CSI Pro	.40 SW	1506	3.5"
CSI Pro	.40 SW	1523	4"
CSI Pro	.40 SW	1603	5"
CSI Pro	.40 SW	1102	5.5"
CSI Pro	.40 SW	1114	5.5"
CSI Pro	.40 SW	1118	5"
CSI Pro	.40 SW	1125	5"
CSI Pro	.40 SW	1532	5"
CSI Pro	.45 ACP	1153	7"
CSI Pro	.45 ACP	1203	6"
CSI Pro	.45 ACP	1207	7"
CSI Pro	.45 ACP	1215	7"
CSI Pro	.45 ACP	1219	7"
CSI Pro	.45 ACP	1222	5"
CSI Pro	.45 ACP	1227	6"
CSI Pro	12ga	1507	7"
CSI Pro	12ga	1515	6"
CSI Pro	12ga	1524	6"
CSI Pro	12ga	1530	6"
CSI Pro	9mm	1415	5"
CSI Pro	9mm	1417	6.5"
CSI Pro	9mm	1422	6.5"
CSI Pro	9mm	1331	5"

Table 6. *Casing recovery information*

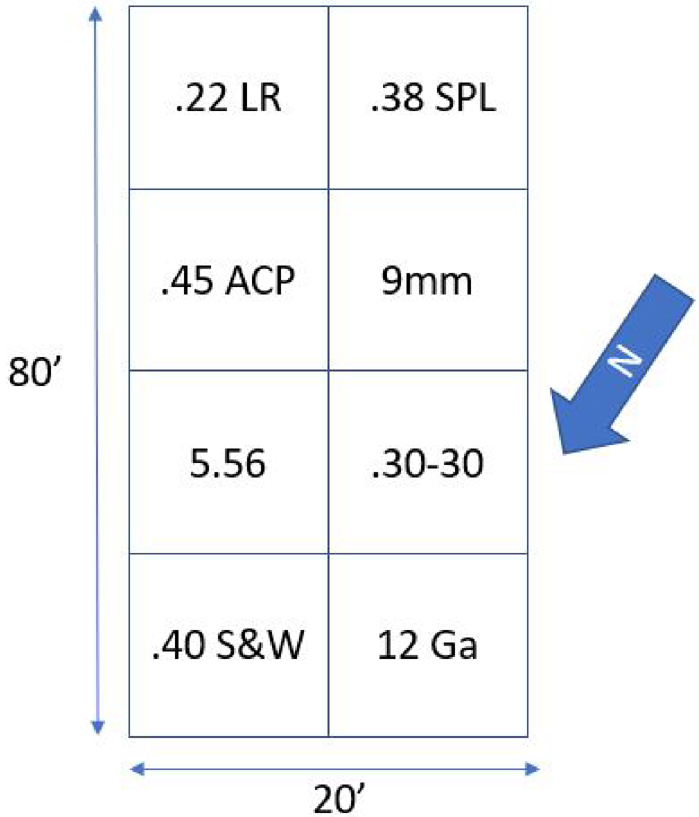

Figure 10. *Grid layout of experiment site*

	Casing Recovery			
		Recovered	Unrecovered	Total
Response variable	9mm	4 (8.3%)	6 (18.8%)	10 (12.5%)
	.40 SW	9 (18.8%)	1 (3.1%)	10 (12.5%)
	.45 ACP	7 (14.6%)	3 (9.4%)	10 (12.5%)
	5.56mm	7 (14.6%)	3 (9.4%)	10 (12.5%)
	.30-30	9 (18.8%)	1 (3.1%)	10 (12.5%)
	12ga	4 (8.3%)	6 (18.8%)	10 (12.5%)
	.38 SPL	8 (16.7%)	2 (6.3%)	10 (12.5%)
	.22 LR	0 (0%)	10 (31.3%)	10 (12.5%)
	Total	48 (100%)	32 (100%)	**80 (100%)**

Table 7. *Chi Square test parameters*

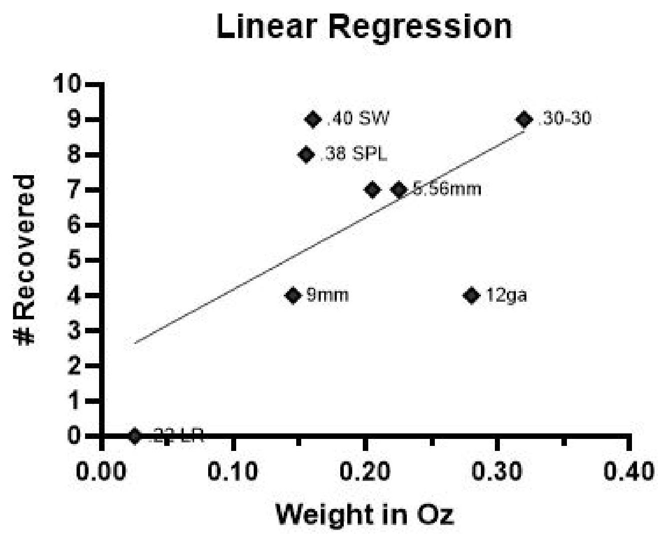

Figure 11. *Linear Regression of casings recovered and weight in ounces*

The resulting r value was 0.595, indicative of a moderate positive correlation. A depiction of this relationship was documented in figure 11. The resulting P-Value was 0.0598. Consultation with publicly available P-Value charts revealed these results were not significant with an alpha value of 0.01 or 0.05, but were significant when alpha was set to 0.10.

Research Results and Discussion

This research demonstrates the ability of two different battery-powered portable metal detectors to detect firearms evidence under snow and ice (see Figure 12). Further, the research demonstrates the difficulty CSIs may experience when searching for small caliber casings, including the popular .22 LR and 9mm, which were detected at 0% and 40%, respectively. Additional consideration should be given to shotgun casings, as their composition is mostly plastic with only the metallic base, in this case steel, for the detectors to locate. Consultation with the Agent who assisted with dispersing the casings revealed he lightly tossed a number of the casings while others were dropped straight down, indicating variation in the orientation of the casings as they laid within the experiment area. It is theorized the orientation of the casing could affect the ability of the detector to return a response. For example, if a casing were oriented vertically within the snow, the end of the casing presents a smaller target than if it were oriented horizontally.

On a real-world scene, deciding where to begin searching for casing evidence could prove complicated. Factors such as the amount of time and current weather (snow) conditions may impede the CSI. Fortunately, several forensic disciplines including forensic meteorology and shooting incident reconstruction may reveal the most probable areas to begin searching. Shooting distance determination coupled with ejection pattern studies may assist the CSI in narrowing the search area considerably for the elusive casing or casings.

Scene search efforts, including those at snow scenes, should be conducted with appropriate team management to ensure the safety of the CSI teams and to mitigate fatigue. Examples include regular rotation into a warming area such as a tent, vehicle, or command post, ensuring enough CSIs are present for the size of the search area, and having a secondary team available for a final walkthrough and clearance of the scene. Appropriately sized personal protective equipment (PPE) is also important, so as to ensure the PPE can fit appropriately over the CSI's base/warming layers whilst minimizing any potential contamination of the evidence.

Limitations

A number of limitations impacted this study, the foremost of which was the limited ability of the researcher to travel between George Mason University (GMU) and the experiment site at Fort Drum. This limited the number of days available for both the bench tests and the collection experiment. Further, the unpredictable nature of upstate New York weather made it difficult to accurately assess when travel should be planned. Ideally, future research of this type would be conducted with the researcher co-located at the experiment site.

An additional limitation to this study was fatigue, as the researcher processed all eight girds by himself. The time associated with the search of each grid coupled with the inclement weather may have impacted the detection of the casings. D'Souza (2017) analyzed the effects of fatigue on CSIs and noted fatigue contributed to increases in mistakes, slower reaction times, and impaired judgement.

Figure 12. *Recovery results*

Conclusion

CSIs must be prepared to operate in any climate type. This research demonstrated it is possible to locate casing evidence beneath the snow using common handheld metal detectors. Many jurisdictions may be limited in the type of equipment available for scene search. When access to other systems such as Forward Looking Infrared (FLIR) or Ground Penetrating Radar (GPR) is limited, a good metal detector like the CSI Pro, which retails for approximately $750, is crucial. Further, FLIR may not be viable in snow scenes given the cold ambient temperatures associated with snow.

Future research may seek to examine the effectiveness of metal detectors at snow scenes of differing depths, as this experiment was constrained to approximately 7” of accumulation. Additional experiments of a more controlled nature assessing casing orientation at varying depths would also be beneficial. Further projects may also seek to examine the effects of snow, ice, and temperature on the recovery of latent prints or DNA from the casings.

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