RECOVERY OF LATENT FINGERPRINTS AFTER IMMERSION IN VARIOUS AQUATIC CONDITIONS

by

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of
Master of Science
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Bachelor of Arts
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABSTRACT

URECOVERY OF LATENT FINGERPRINTS AFTER IMMERSION IN VARIOUS AQUATIC CONDITIONS

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George Mason University, 2011

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As the use of waterways continues to increase for recreational purposes, so do the incidents of criminals using waterways to dispose of evidence. Although some may believe that items recovered underwater will have no forensic value, this research shows that identifiable fingerprints may still be recovered. An experiment was conducted to establish the value of latent fingerprint evidence that had been submerged in a natural aquatic environment. The two factors analyzed in this study that affect the deterioration rate of latent fingerprints were stream current and length of time submerged. To evaluate these factors, latent fingerprints were deposited on metallic objects simulating the substrate of a knife or gun and submerged in a freshwater stream at locations subject to various powers of current for 24, 48, and 72 hours. After recovery, the items were subjected to cyanoacrylate fuming followed by black powder processing; the prints were lifted with tape and examined. Each print was evaluated for its individualizing power based on a scoring system. Latent fingerprints subjected to higher current velocity were

significantly more deteriorated than prints subjected to little to no current. A decrease in latent fingerprint visualization with longer periods of submersion was also observed. The results of this study demonstrate the importance of understanding the interactions between latent fingerprints and the various factors of the natural aquatic environment to better aid in criminal investigations and potentially linking evidence to a perpetrator.

INTRODUCTION

Recreational waterways draw visitors in immeasurable numbers, especially during the summer months. As the number of people using recreational waterways increases, the incident rate of accidents, drowning, violent crimes, and homicides also increases. In the three year period between 1997 and 2000, more than 120 bodies were recovered from the waterways of New York City alone (Lucas, Goldfeder, & Gill, 2002). Criminals often seek waterways as an ideal place of disposal for weapons and other evidence of wrongdoing. For these reasons, it has become the responsibility of law enforcement agencies to provide resources that can retrieve evidence from diverse types of aquatic environments (Becker, 2006).

Seventy percent of the Earth's surface is covered in water. The United States alone has more than 250,000 rivers totaling over 3.5 million miles (*American Rivers*, 2011). What better place to dispose of incriminating evidence? A common switchblade or a 9mm revolver in the mud of a flowing river may seem unlikely to ever see the light of day, and even if found, may seem unlikely to retain biological fluids, fibers, or latent fingerprints. However, as technology and procedures in marine archaeology continue to advance, the likelihood of recovering evidence from waterways is higher than ever (Becker, 2006; Dutelle, 2007). Criminals and law enforcement entities alike have been surprised by the physical evidence that remains despite hours, days or even years underwater. Becker (2006) shares the following case study:

> In a search conducted at Canyon Lake in Texas for a firearm, divers found shell casings on the bank and in the shallow water adjacent to the area at which witnesses placed the suspect who threw the weapon in the water. The shell casings were of the same caliber as the weapon recovered, and since the shell casings were processed as evidence, the crime laboratory was able to lift a fingerprint from one of them. (Becker, 2006, p. 78)

Law enforcement agencies across the globe are beginning to understand the importance of treating underwater crime scenes like those above land—it is important for divers to systematically process and document the scene of the recovery, whether it is a death investigation or the recovery of a weapon.

Introduction to Fingerprints

Fingerprints are one of the oldest and most widely accepted forms of forensic evidence (Houck & Siegel, 2006). Accordingly, fingerprints are the most common method used by law enforcement to positively identify a person (Gaensslen, 2009). Fingerprints are unique to each individual and remain unchanged throughout a person's lifetime unless damage is done to the dermal skin layer (i.e. scars or burns). Friction ridge patterns of the volar pads of the fingers make up each fingerprint. Friction ridge patterns are a complicated pattern of hills (ridges) and valleys (furrows). These patterns are formed in the womb during the 9^{th} or 10^{th} week of fetal development and ultimately appear on the surfaces of the fingers, hands, and bottoms of feet (Houck & Siegel, 2006).

This development is formed entirely from environmental factors and is not influenced by genetics, which attributes to the uniqueness of fingerprints. Figure 1 illustrates the three basic fingerprint patterns (arch, loop, and whorl) and the composite pattern, which is a combination of two or more of the basic patterns. Figure 1 also identifies two points commonly recognized in a fingerprint pattern: the core and the delta. The core is the central part of the fingerprint pattern, and the delta is the point where two ridges called type lines diverge (Galloway & Charlton, 2006). Loop fingerprint patterns have one core and one delta; whorl fingerprint patterns have one core and at least two deltas, whereas arches have no core or delta (Houck & Siegel, 2006). There are also several other more specific categories recognized by fingerprint examiners. For instance, a loop may be further classified as radial or ulnar depending on the direction of the friction ridge impressions. The features used to individualize a print are called minutiae.

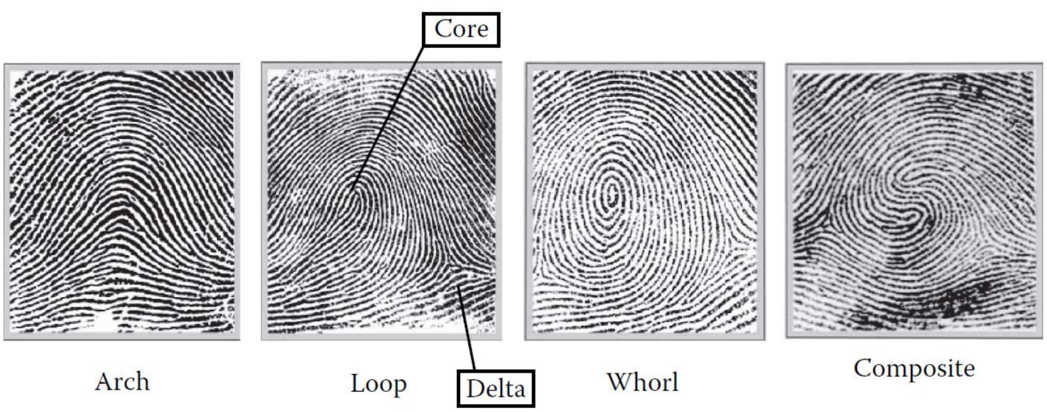

Figure 1: Basic fingerprint patterns (Galloway & Charlton, 2006)

Minutiae are formed when the ridges of the fingerprint end abruptly (i.e. ending ridge), split into two ridges (i.e. bifurcation), or are short in length (i.e. dot). Combinations of these features may also form to create more unique minutiae. For instance, two bifurcations facing each other form a feature called an *island* or *lake*. Figure 2 illustrates some of the ridge characteristics commonly identified by fingerprint examiners.

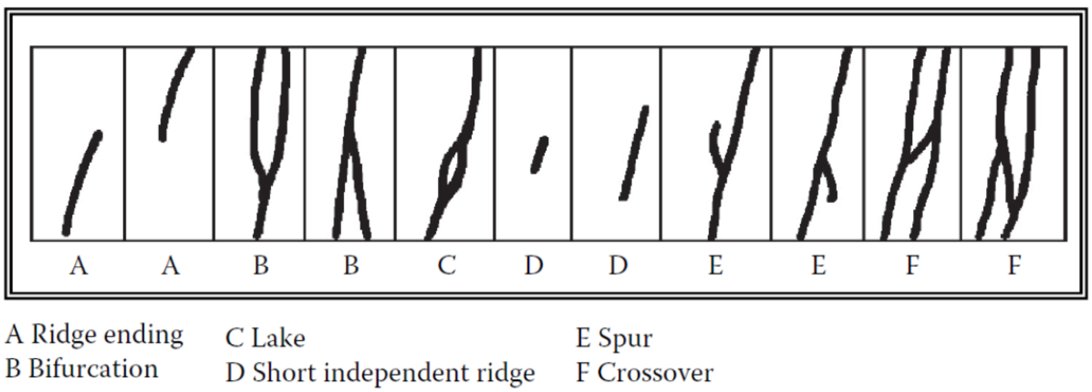

Figure 2: Common ridge characteristics (Galloway & Charlton, 2006)

Latent fingerprints are impressions of the friction ridge skin deposited on a surface. The sweat glands found underneath friction ridge skin produce a watery-type composition which forms the basis for latent fingerprint residue. When a person touches other parts of the body, such as the face or scalp, the organic molecules produced here also become part of the latent print residue. Ultimately, latent fingerprints are composed of various minerals, fats, acids, salts, oils, and water.

The process of rendering latent fingerprints visible is called *development*, *enhancement*, or *visualization*. The method of enhancement will depend on the type of surface the print has been deposited on (i.e. porous, such as paper, or non-porous, such as glass). The oldest, most common, and simplest physical method used to visualize latent prints on a non-porous surface is powder dusting (Houck & Siegel, 2006; Sodhi & Kaur, 2001). This includes lightly brushing fine particles across a print, usually with a fiberglass or camel-hair brush. The powders consist of a resinous polymer that adheres to the fingerprint residue and enhances the friction ridge pattern (Sodhi & Kaur, 2001). Powders in a variety of colors and fluorescence can be used to best visualize a latent print light or dark surfaces. Black powder is the most frequently used because it creates the best contrast when the print is applied to a white card, often used for filing and recording friction ridge prints (Houck & Siegel, 2006).

Cyanoacrylate fuming, commonly known as "superglue" fuming, is a chemical process used to visualize latent fingerprints on non-porous items. It is one of the most widespread methods because of the versatility and ease of use of a fuming chamber, which can be constructed with easily acquired equipment (Kubic & Petraco, 2009). Although more advanced fuming chambers exist, a simple apparatus can be constructed under an exhaust hood using a small fuming chamber, a 100 ml beaker of fresh hot water, a warming plate, and a clean aluminum cup with a dime-sized drop of cyanoacrylate.

When the item with potential latent prints is placed inside the fuming apparatus, the warming plate heats the cyanoacrylate, forming vapors which surround the sample and adhere to the moisture of any latent fingerprints. The hot water in the chamber helps create humidity to enhance the moisture of the latent prints. Prints with higher moisture content have been found to respond best to this development process (L. Lewis, Smithwick, Devault, Bolinger, & S. Lewis, 2001). The cyanoacrylate forms a whitish residue on the print and makes it semi-permanent. The print can then be dusted with powder, which will adhere to the cyanoacrylate residue. The print can potentially be collected several times without destroying the print.

Although recovering latent fingerprints from a glass table or mirror may be easily done using the powder dusting method, not all surfaces are as straightforward. For instance, some metallic surfaces, like the blade of a knife, are textured or grainy as a result of how the metal was forged. Techniques such as cyanoacrylate fuming have been developed to aid in the recovery of latent fingerprints from unusual and textured surfaces (Warrington, 2011). It is important for crime scene specialists to evaluate the surface before determining which processing technique to utilize.

Many factors affect the deterioration of latent fingerprint residues, including the type of surface, temperature and humidity of the environment, the presence of light, weather conditions, as well as immersion in water (Baniuk, 1990; Barnett & Berger, 1976). These factors also influence the effectiveness of some development techniques. There are many anecdotal accounts that illustrate the durability of latent fingerprints, even those subject to harsh conditions such as extreme weather or immersion in a rapidly flowing river (Vandiver, 1976).

Latent fingerprints are especially valuable pieces of physical evidence in a criminal investigation because of their ability to identify a perpetrator. In 1999, the Federal Bureau of Investigation (FBI) created the Integrated Automated Fingerprint Identification System, or IAFIS, which is a database of digital fingerprint images searchable using software that is standard across most law enforcement agencies. According to Houck and Siegel (2006), investigators can use IAFIS to:

> (1) Enhance an image to improve its quality, (2) compare crime scene fingerprints against known 10-print records retrieved from the database, (3) search crime scene fingerprints against known fingerprints when no suspects have been developed and (4) automatically search the prints of an arrestee against a database of unsolved cases. (p. 528)

Case Studies on Recovering Submerged Latent Fingerprints

Several case studies have been published on the success of recovering latent prints from diverse surfaces exposed to aquatic environments for various periods of time (Vandiver, 1976). In 1971, a television stolen in a burglary was found in a river three and a half weeks after the incident. The television sat in an evidence room for two weeks before it was processed for latent prints. Several identifiable palm prints were discovered on the wood underneath the set. This evidence led police to obtain a confession from a suspect with whom the prints matched. The perpetrator admitted the television was dumped in the river on the night it was stolen and remained in the rapidly flowing water for over three weeks. In the words of former Police Officer George Throckmorton, "The only way to know for sure is to process the article and see if anything develops" (Anonymous, 1971).

The case of the S.S. Brother Jonathan shipwreck recovery fully illustrates the resilience of latent prints. On July 30, 1865, the S.S. Brother Jonathan, carrying 244 passengers and crew and a large shipment of gold, crashed into an uncharted rock off the coast of California. Only 19 survived, making it the deadliest shipwreck up to that time on the Pacific Coast of the United States (Powers, 2006). In 2006, scientific divers began the recovery of the SS Brother Jonathan. Becker (2006) recounts the following:

> Gold coins were recovered, although they were corroded and virtually unrecognizable. The coins were placed in the hands of a team who removed the corrosion chemically, revealing the coin beneath. The coins were in perfect condition, as if recently released by a bank. Beneath the corrosion on one coin was a human fingerprint, intact and discernible, awaiting the light of day. (p. 131)

Although case studies, such as those described previously, are helpful records, it is important for forensic scientists to have data of greater scientific origin to reference when testifying in the court of law about the lifetime of a submerged friction ridge impression instead of relying on possibly biased personal experiences. The judge in a criminal trial is the ultimate gatekeeper in deciding the admissibility of expert testimony. As a result of the ruling in the Supreme Court case *Daubert v. Merrell Dow Pharmaceuticals* (1993), a list of standards were created to determine the admissibility of expert scientific testimony. The requirements have been summarized by Kiely (2006) as such:

> (1) Whether a theory or technique can be (and has been) tested; (2) whether it has been subjected to peer review and publication; (3) whether, in respect to a particular technique, there is a high known or potential rate of error, and whether there are standards controlling the technique's operation; and (4) whether the theory or technique enjoys general acceptance within a relevant scientific community. (p. 18)

Ultimately, it is the judge's decision whether an expert's testimony is admissible. In the case Kumho Tire v. Carmichael (1999) the court concluded Rule 702 of the Federal Rules of Evidence (*Federal Rules of Evidence*, 1999) "grants the district judge the discretionary authority… to determine reliability in light of the particular facts and circumstances of the particular case" (Kiely, 2006, p. 19). Therefore, it is the goal of forensic scientists to meet these standards so as to ensure their testimony will be admissible and of high scientific integrity when met with scrutiny in judicial proceedings. For this reason, it is important that research on the topic of recovery of latent fingerprints from aquatic conditions continue to be conducted.

Previous Studies on Recovering Submerged Latent Fingerprints

As early as the 1960s, researchers were beginning to realize water may have less of an effect on latent prints than commonly thought. In a study conducted by the St. Paul Police Crime Laboratory (Hanggi & Alfultis, 1969), latent prints were deposited on several glass slides and immersed in a beaker of water. After one day, one slide was removed from the beaker and dried at room temperature. Prints of excellent quality were visualized using "Brilliant Red" fingerprint powder. After six more days, a second slide was removed from the beaker and processed in an identical manner. Researchers reported the prints from the one-week old sample to be of equal quality to the prints on the one-day old sample. The third slide remained in the beaker of water and was rotated for an hour and a half at 150 rpm, swirling the water over the print. Still, development with fingerprint powder yielded a print of excellent quality. In an effort to see if these results were representative of a real-case scenario, the researchers deposited more prints on a square of plate glass and set it outside in the Minnesota weather for one week. Despite exposure to two days of sleet, rain, snow and sub-zero weather, latent prints of excellent quality were obtained by dusting with “Indestructible White” powder.

In a recent study by Soltyszewski et al. (2007) in Poland, the authors instructed eight donors to deposit prints from three fingers on 152 clean glass slides (a total of 456 prints). The glass slides were submerged in containers filled with river, sea, tap, or distilled water at 5°C and 20°C. A sample of slides was recovered on day 1, 7, 14, 21, 28, and 42 of the experiment. After air-drying, the fingerprints were developed with aluminum powder, ferromagnetic powder, or cyanoacrylate fuming. The authors then assessed the visibility of the three fingerprints on each slide using the following scale: 5- very good visibility, 4- good visibility, 3- poor visibility (barely identifiable prints), 2- bad visibility (no identifiable prints), 1- blur, or 0- no prints. As expected, Soltyszewski et al. found a decrease in latent fingerprint visualization as the length of time submerged increased. A reduction in development success was observed on latent fingerprints subjected to the higher temperature water (20°C). However, they found that prints submerged for one and seven days were on average of good to very good visibility. Prints of good visibility were developed after as long as 21 days using ferromagnetic powder (see Table 1).

Table 1: Mean visibility scores for latent fingerprints submerged in water (Soltyszewski, 2007)

Days submerged in river water	1			7			14			21			28			42		
Treatment	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C
Temperature 5 °C	5	4	5	4	2	4	4	2	4	3	1	3	2	0	3	0	0	3
Temperature 20 °C	5	5	5	2	3	3	2	2	3	1	1	2	1	0	1	0	0	1
Days submerged in sea water	1			7			14			21			28			42		
Treatment	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C
Temperature 5 °C	5	4	5	4	3	4	4	2	2	4	2	2	3	0	2	3	0	0
Temperature 20 °C	5	4	5	2	3	3	1	2	2	0	2	1	0	1	1	0	0	0
Days submerged in tap water	1			7			14			21			28			42		
Treatment	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C
Temperature 5 °C	5	5	5	5	3	4	4	3	3	4	2	1	3	2	1	3	2	0
Temperature 20 °C	5	5	5	4	3	3	3	3	2	1	2	2	1	1	0	0	1	0
Days submerged in distilled water	1			7			14			21			28			42		
Treatment	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C	F	A	C
Temperature 5°C	5	5	5	5	5	4	4	3	4	4	3	2	3	3	2	3	2	1
Temperature 20°C	5	5	4	5	5	4	4	3	3	3	3	2	3	2	2	2	1	0

F: ferromagnetic powder; A: aluminum powder; C: cyanoacrylate
5 = very good visibility
4 = good visibility
3 = poor visibility (barely identifiable prints)
2 = bad visibility (no identifiable prints)
1 = blur
0 = no prints

This supports the conclusions by Midkiff (1993) and others (Armstrong & Erskine, 2011; Becker, 1995; Yuille, 2009) that environmental conditions, namely immersion in fresh and salt water, may have less effect on fingerprint recovery than commonly thought.

Several studies with methodologies similar to those performed by (Hanggi & Alfultis, 1969; Soltyszewski et al., 2007) have been conducted to evaluate the effect of an aquatic environment on the development of latent fingerprints. However, few studies utilize a realistic aquatic environment in place of a laboratory. Yuille's (2009) study was the first to investigate the deterioration of latent fingerprints on a metallic substrate submerged in various depths of a natural aquatic environment. In this experiment, the author used his right thumb to deposit friction ridge impressions on sixty metallic knives of identical origin. Thirty of the sixty knives served as a control and were placed in an area where they were allowed to air dry undisturbed for 168 hours. The remaining thirty knives were submerged in one of two locations in Lake Ontario at various depths for up to 168 hours. Samples in Location 1 were subject to midway submergence (1.5 m from the surface of the water) and included submergence intervals of 1 hour, 3, 6, 8, 12 and 24 hours. Samples in Location 2 were subject to either midway or bottom submergence (1.5 m and 3.0 m respectively). Samples submerged midway at Location 1 and Location 2 were retrieved after 24 and 168 hours. Bottom submerged samples from Location 2 were retrieved after 12, 24 and 168 hours. These submergence intervals were chosen so that they could be directly compared to samples at Location 1 at critical time periods.

Upon recovery, the knives were air-dried and subjected to black fingerprint powder for development of the friction ridge impressions. The sample impressions were then compared to a standard impression created by the author. To evaluate the deterioration and the individualizing power of the print, the author determined the number of minutiae in similarity (out of 30) between the sample and the standard. An identical process was used for the control impressions.

The mean minutiae counts of the samples from their respective depths were compared using statistical analyses. The author determined that the individualizing power of the prints was dependent on the depth of their submergence in water; however, time submerged was an important factor. In general, Yuille observed a decrease in the number of individualized friction ridge impressions over time (see Figure 3). Samples submerged for 24 hours at 1.5 meters maintained a higher mean minutiae count compared to 24 hour samples at 3.0 meters. However, after 168 hours of submergence, samples submerged at 1.5 meters had a lower mean minutiae count compared to samples from 3.0 meters, indicating an external factor was at play, such as sediment protection for those samples placed at the bottom of the lake amidst sand. The two locations used in the experiment were very different: "Location 1 contained macrophytes [aquatic plants and algae], was subject to wave interaction and was composed of a compact 'mud-like' sediment whereas there were no macrophytes present at Location 2, minimal wave interaction and the sediment was composed of a 'loose-sand' substrate" (Yuille, 2009, p. 51). As a result of the numerous extraneous circumstances at play, it is difficult to determine which factor had the largest effect on the quality of the fingerprints recovered. Although it would be useful to evaluate each of these variables independent of one another, the characteristics of rivers and streams tend to make this impossible since wave interaction changes with depth, and as a result, so does aquatic plant growth and sediment type.

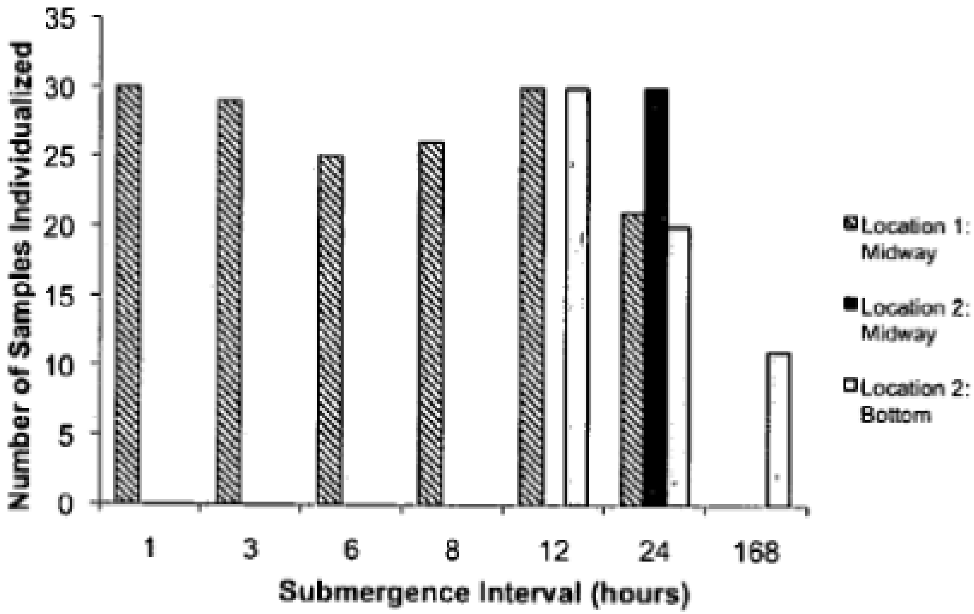

Figure 3: Number of individualized latent fingerprints for each submergence interval at Location 1 and Location 2 (Yuille, 2009)

THE CURRENT STUDY

The vast majority of previous studies have utilized controlled laboratory environments (e.g. containers of water or aquariums) to determine the lifetime of a latent print submerged in water. However, these controlled conditions do not accurately represent the environmental factors in which an incriminating weapon would be disposed. Few researchers have attempted to conduct experiments in a natural aquatic environment as did Yuille (2009). These conditions more accurately represent the environmental factors evidence may be affected by, such as sediment type, varying pH, aquatic plant and animal life, or weather. Therefore, the current study evaluated the effects of submergence in freshwater on the recovery of latent fingerprints in a more realistic setting with non-porous objects that closely mimic those of evidentiary value, such as a knife used in an assault.

The current experiment is based largely upon the work of Yuille, whose 2009 study was the first to investigate the interaction of sediment with submerged friction ridge impressions. Yuille (2009) suggested different aquatic environments (such as salt water, streams and rock or clay sediment) be examined to determine the effects of these variables on the deterioration of friction ridge impressions. However, Yuille's work experimented solely with black powder processing. Samples in the current study were subjected to another commonly used method in addition to black powder; cyanoacrylate fuming is frequently used due to its versatility for the array of items found at crime scenes.

Specifically, this study determined the effect of current velocity and length of time submerged on the deterioration of friction ridge impressions on metallic blades submerged in freshwater. To continue in the tradition of Yuille, this experiment took place in a natural aquatic environment, namely, a freshwater stream in Fairfax Station, Virginia that can be best described as slow and rippling, with alternating areas of narrow and wide passages, faster and slower currents respectively. Two locations were used to assess the effect of current velocity: Location 1 is at the area of highest current velocity and Location 2 is at the area of lowest current velocity. Since previous studies on this topic have not been conducted in the author's geographical area, this study may serve as a reference for forensic scientists in the Northeast United States where environmental factors may differ from locations where previous studies were conducted (e.g. Poland or Canada).

Two hypotheses were tested in this study. (H1) Print visibility scores were anticipated to be inversely related to the current velocity due to the increased likelihood of latent fingerprint deterioration as a result of increased sediment, macrophyte and wave interaction at Location 1. Therefore, mean print visibility scores were expected to be lower at Location 1 than at Location 2 for each submergence interval. (H2) Print visibility scores were expected to be negatively correlated with the length of time submerged due to the belief that latent print residues deteriorate over time and prolonged exposure to aquatic conditions will attribute to overall deterioration of friction ridge impressions. Thus, mean print visibility scores were expected to decrease as length of time submerged increases at both Location 1 and Location 2. Each location was analyzed independently, as was each submergence interval.

Method and Materials

Friction ridge impressions were deposited on eighteen stainless steel eight inch blades. The experiment included three successive trials, with six blades in each trial. Two blades served as controls and the remaining four were submerged in a freshwater stream: two in high current (Location 1), two in low to no current (Location 2). Trial 1 proceeded for 24 hours, Trial 2 for 48 hours, and Trial 3 for 72 hours.

Each blade was permanently labeled with a unique number ranging from 1through 18 using a Sharpie marker. All the blades were from the same manufacturer and from the same model. The author's right thumb was used to deposit all of the friction ridge impressions onto the surface of the blades. First, each blade was cleaned using alcohol swabs to ensure no unintentional prints were left. The right thumb was wiped down the bridge of the nose and subsequently wiped across the forehead and under the chin to ensure that adequate oils are collected on the thumb before each deposition. Next, five friction ridge impressions were deposited onto one side of each blade. Performing the same pre-deposition routine ensured results of latent fingerprint recovery were as consistent as possible. To ensure quality prints were deposited, each print was inspected with oblique lighting. If the print was smudged or appeared to contain inadequate amounts of oil, the blade was cleaned and the process will began anew. When all five prints had been deposited on the blade, the prints were labeled *a* through *e* from left (closest to the handle) to right (the tip of the blade). With the exception of print deposition, latex gloves were worn at all times when handling the blades to avoid contamination or the deposition of unintentional prints.

To function as a control, six of the eighteen blades prepared above were not submerged in water and were instead placed in a low-traffic area where they were allowed to sit undisturbed for the remainder of the experiment. The experimental samples were all submerged in the freshwater stream in three successive trials. Each trial began one hour after friction ridge deposition. This was meant to replicate the lapse of time between the use of a weapon in a crime and the time in which it is disposed of in a waterway. Two locations were used to assess the impact of variations in the stream velocity.

In each trial, two blades were placed print-side-up at Location 1 (L1). L1 is positioned at the center of a narrow (1 ft wide) and shallow (1-2 in deep) area of the stream where the current is highest and relatively free of aquatic plants. The bed of this location is sandy with small pebbles. The remaining two blades were placed at Location 2 (L2). L2 is situated approximately 2 feet away from L1 in a wide (6 ft) and deep (2 ft) portion of the stream, where it was subjected to the stream's slowest current and was relatively free of aquatic plants (see Figure 4). The three trials took place successively within three weeks to ensure variables such as outdoor and water temperature were comparable. However, it was inevitable that some variation occurred.

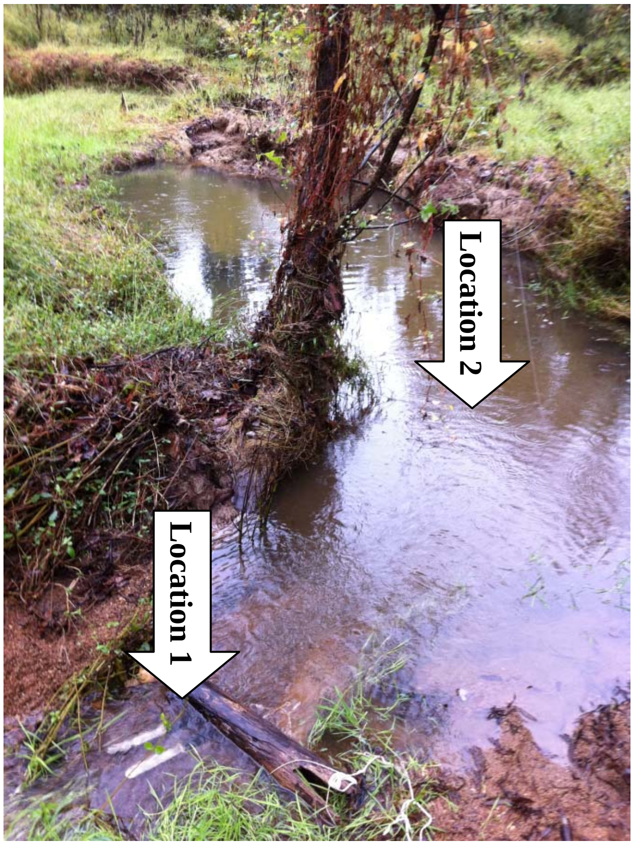

Figure 4: Location 1 is situated at the stream's highest current and Location 2 is positioned in an area of low to no current

In Trial 1, the average air temperature was 70°F and the water temperature at L1 and L2 was about 65°F. During Trial 2, the average air temperature was 56°F and the average water temperature at L1 and L2 was about 60°F. Throughout Trial 3, the average air temperature was 60°F and the average water temperature at L1 and L2 was around 60°F. A rainstorm of varying degrees occurred once during each trial, which slightly elevated the stream’s water levels. Aside from the brief rainstorms, the weather was on average sunny with intermittent clouds.

The stream velocity may be affected by rainfall, since the stream is located in a developed watershed and is therefore subject to drainage from neighboring areas (Michaud, 1994). The velocity of water also changes with depth (Michaud, 1994). Stream velocity tends to be at its greatest midstream near the surface and at its slowest along the stream bed and banks due to friction caused by sediment (Wetzel, 2001).

Using a method suggested by Michaud (1994), a rough estimate of the stream velocity at L1 was determined by timing the movement of a float down the stream. Across three separate measurements, the float moved 10 feet in an average of 24 seconds. By using the standard equation for measuring velocity (distance/time = velocity), the stream velocity was calculated to be approximately 0.42 feet per second. Although the required equipment was not available to measure the velocity of the stream at L2, based on knowledge gathered by hydrologists (Michaud, 1994; Wetzel, 2001), we know that the bottom of the stream will have the slowest current.

After the time allotted for each trial, the blades from L1 and L2 were recovered from the stream and allowed to air-dry during their transport to the laboratory, which took no longer than one hour. All blades were then processed by cyanoacrylate fuming. To create the cyanoacrylate fuming apparatus, the fuming chamber was placed underneath an exhaust hood. Within the chamber was the following: a 100 ml beaker of fresh hot water, a warming plate, and a clean aluminum cup with a dime-sized drop of cyanoacrylate (see Figure 5).

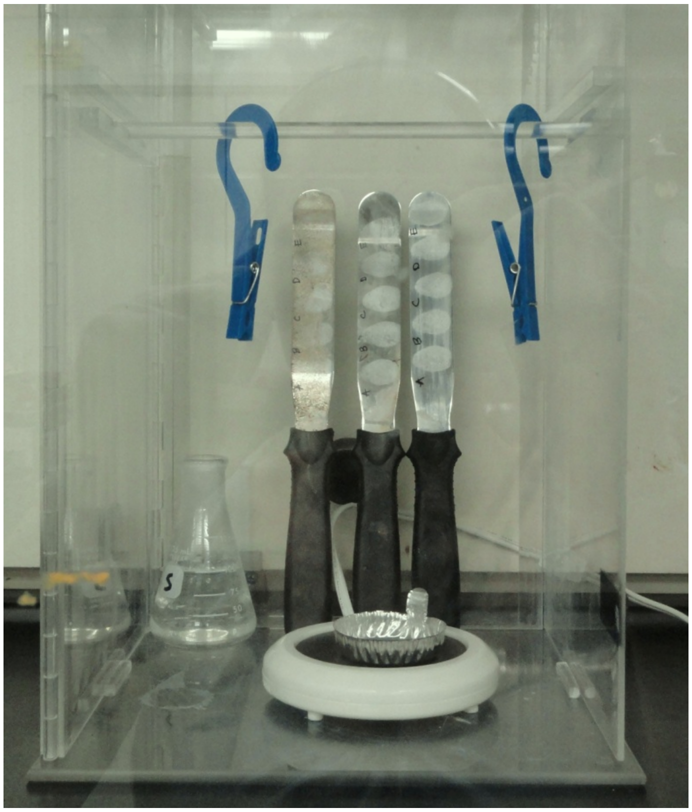

Figure 5: The components of the cyanoacrylate fuming chamber

To function as a control, several thumb prints were deposited on a sheet of acetate using the same pre-deposition routine and then hung in the fuming chamber. The items that were to be tested were placed inside the chamber and the warming plate (with the aluminum boat containing cyanoacrylate on top) subsequently turned on. The blades in each trial were processed in two groups of three: one control blade, one blade from L1 and one blade from L2. With the chamber door closed, the items were processed for approximately eight uninterrupted minutes. The acetate control was carefully watched to determine when both the control and test items reached optimum development to prevent over processing. The warming plate was unplugged and the door to the chamber opened to allow the remaining cyanoacrylate vapors to escape. The fuming chamber door remained open and the exhaust hood sash closed for 15 minutes to ensure all fumes had escaped. After retrieval from the fuming chamber, the samples were left undisturbed for one hour to allow the cyanoacrylate to anneal.

After one hour, each item was dusted for prints using Dust Bustr© black powder. A Sirchie© fiberglass filament brush was used to collect small amounts of the powder which were then lightly dusted over the white residue of the cyanoacrylate using a twirling motion to ensure a consistent and even dusting of powder. Throughout this whole process, goggles, gloves and masks were worn for safety since the cyanoacrylate fumes and the black powder can be hazardous if inhaled.

Finally, each print was lifted using Sirchie© fingerprint tape, placed on a white card and examined using a magnifying glass. Each print was assessed using a scoring system similar to the Soltyszewski et al. study (Soltyszewski et al., 2007) based on the visibility of the recovered print, and therefore a measure of the individualizing power of the friction ridge impressions. The scoring was determined as follows (see Figure 6):

5 – **Very Good Visibility**: Clearly defined friction ridges across entire print. Classifiable as one of the three basic fingerprint patterns (arch, loop, or whorl). Core (center point) and minutiae (individual features, e.g. bifurcation, ending ridge) are visible.

4 – **Good Visibility**: Clearly defined friction ridges are visible across majority of print. Classifiable as one of the three basic fingerprint patterns (arch, loop, or whorl).

3 – **Poor Visibility**: Friction ridges are only visible on portion of print. The print cannot be classified into one of the three basic fingerprint patterns. Print may be smudged.

2 – **Bad Visibility**: No friction ridges are visible. Print is almost completely smudged or obscured and cannot be classified into one of the three basic fingerprint patterns.

1 – **Blur/No Print**: No print is visible or only the outline of print is visible.

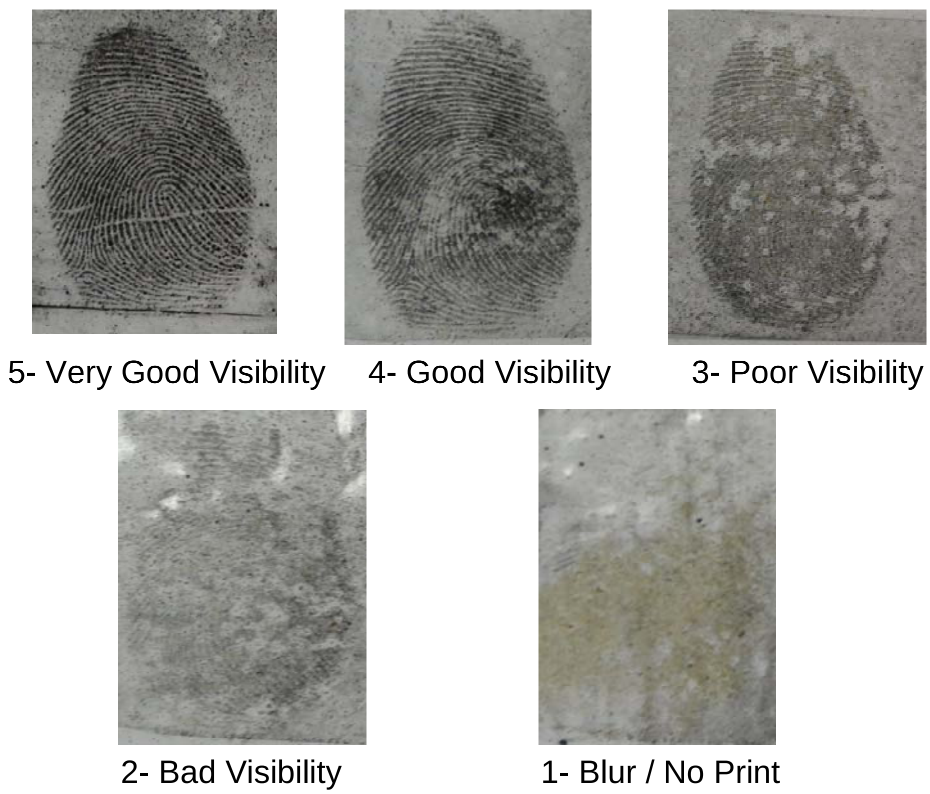

Figure 6: Latent fingerprint visibility scoring system

RESULTS

Statistical analyses were performed using IBM SPSS 20.0 software to test the hypotheses. The mean visibility score was calculated for each item as was a combined mean visibility score for the items in each location (see Table 2).

In Trial 1 (submergence interval= 24 hours), fingerprints recovered from items submerged in L1 (Current) were on average of poor visibility, whereas fingerprints recovered from items submerged in L2 (Non-Current) were on average close to very good visibility. In Trial 2 (submergence interval= 48 hours), fingerprints recovered from items submerged in L1 were on average of poor visibility, while fingerprints recovered from items submerged in L2 were on average of good visibility. In Trial 3 (submergence interval= 72 hours), fingerprints recovered from items submerged in L1 were on average a blur or totally obscured, however fingerprints recovered from items submerged in L2 were still on average of good visibility. In general, latent fingerprints recovered from items submerged in L2 had higher visibility scores than latent fingerprints recovered from items submerged in L1 after 24, 48 and 72 hours. Mean visibility scores for items submerged for 24 hours were notably higher than mean visibility scores for items submerged for 72 hours (see Figure 7).

Two types of correlations were used to test the hypotheses: a Point Biserial Correlation and a Pearson Correlation. The type of correlation chosen depends on the types of independent variable being evaluated. A Point Biserial Correlation is used to evaluate Hypothesis 1 because the independent variable (current velocity) is dichotomous (i.e. there are only two possible values, 0 (non-current) or 1 (current). A Pearson Correlation is used to evaluate Hypothesis 2 because the independent variable (submergence interval) is ordinal (i.e. there are more than two categories, 24 hours, 48 hours, or 72 hours).

Calculating a correlation helps determine the relationship between the independent and dependent variables and may help determine if an independent variable can serve as a predictor of a future outcome. It does not indicate whether a variable *causes* an outcome, but rather whether the variable and the outcome are *related* (Curran, 2011). The significance level (shown as a p value) indicates how reliable the correlation is; a p value less than .05 is considered to be "significant" and thus, reliable.

The first hypothesis stated that latent fingerprint visibility scores would be inversely related to the current velocity due to the increased likelihood of print deterioration as a result of increased sediment, macrophyte, and wave interaction at Location 1. A Point Biserial Correlation was used to analyze the relationship between print visibility scores and current velocity (Location 1/High Current Velocity=1, Location 2/Low or No Current Velocity=0). Results of the Point Biserial correlation showed that in areas of high current velocity, the visibility scores of the recovered latent fingerprints tended to decrease significantly (r (60) = -.55, p=.000). The mean print visibility scores were lower at Location 1 than Location 2 for each submergence interval (see Table 3). Thus, the first hypothesis was supported.

Table 2: Mean visibility scores for Location 1 and Location 2 after 24, 48, and 72 hours of submergence

Trial 1: Submerged 24 hours	***Location 1 (Current)***		***Location 2 (Non-Current)***		***Control***	
Item Number	*1*	*2*	*3*	*4*	*5*	*6*
Mean Visibility Score	3.0	3.6	4.6	4.6	5	5
Location Mean Visibility Score	3.3		4.6		5	
Trial 2: Submerged 48 hours	***Location 1 (Current)***		***Location 2 (Non-Current)***		***Control***	
Item Number	*7*	*8*	*9*	*10*	*11*	*12*
Mean Visibility Score	4.2	2.4	4.2	3.6	5	5
Location Mean Visibility Score	3.3		3.9		5	
Trial 3: Submerged 72 hours	***Location 1 (Current)***		***Location 2 (Non-Current)***			***Control***
Item Number	*13*	*14*	*15*	*16*	*17*	*18*
Mean Visibility Score	1.2	1	3.2	4.4	4.8	5
Location Mean Visibility Score	1.1		3.8		4.9	

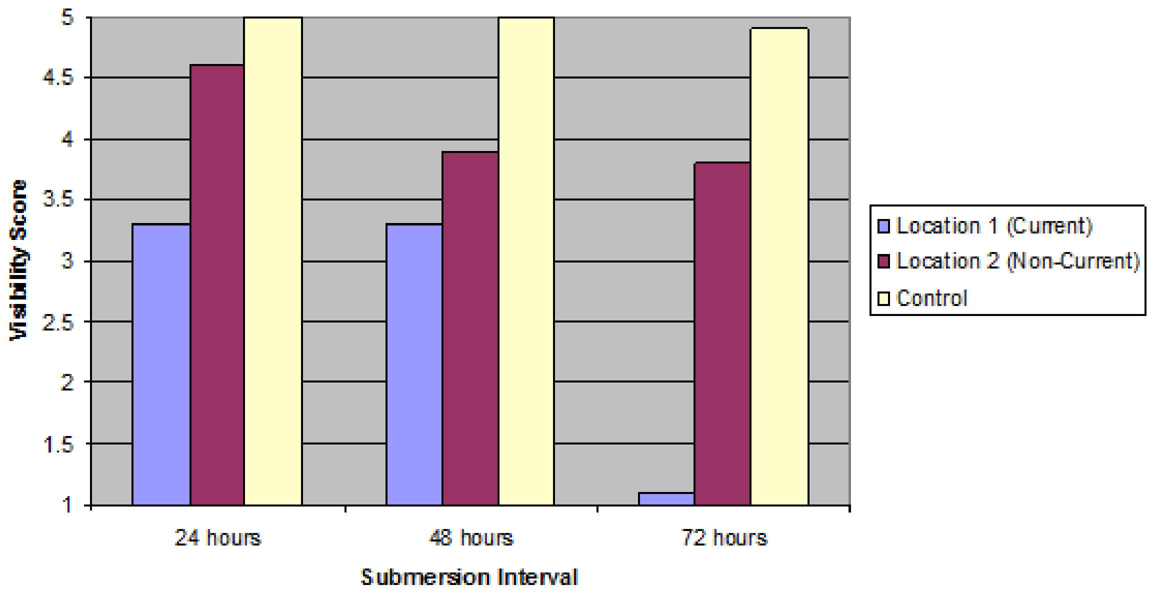

Figure 7: Graph illustrating the dependence of length of submergence time on the visibility score of recovered latent fingerprints from Location 1 and Location 2 with Control scores as a comparison

Table 3: Correlations between visibility scores and current velocity for each submergence interval

	N	Point Biserial Correlation
Submerged 24 hours	20	.67*
Submerged 48 hours	20	-.31
Submerged 72 hours	20	-.83**
Total	60	-.55**

Notes. Current=1, Non-Current=0 *p<.01 **p<.001

The second hypothesis stated that latent fingerprint visibility scores would be negatively related with the length of time submerged due to the belief that latent print residues deteriorate over time and prolonged exposure to aquatic conditions will attribute to overall deterioration of friction ridge impressions. A Pearson correlation was used to analyze the relationship between print visibility scores and length of time submerged. Location 1 and Location 2 were analyzed independently (see Table 4).

Table 4: Correlations between visibility scores and length of submergence interval for Location 1 and Location 2

	N	Pearson Correlation
Location 1 (Current)	30	-.69**
Location 2 (Non-Current)	30	-.33
Total	60	-.44**

Note. **p<.001

Results of the Pearson correlation showed that as the length of time submerged at Location 1 increased, the visibility scores of the recovered latent fingerprints decreased significantly (*r* (30) = -.69, *p*=.000). Mean print visibility scores for Location 1 after 24 hours and 48 hours were the same, but after 72 hours the mean print visibility score was lower. Results of a second Pearson correlation showed that as the length of time submerged at Location 2 increased, the visibility scores of the recovered latent fingerprints decreased, but not significantly ($r (30) = -.33$, $p=.071$). Mean print visibility scores for Location 2 decreased as the submergence interval increased. Therefore, the second hypothesis was partly supported.

DISCUSSION AND CONCLUSION

It is known that the quality of latent fingerprints naturally deteriorate over time (Archer, Charles, Elliott, & Jickells, 2005; Baniuk, 1990; Midkiff, 1993; Yuille, 2009) and this study supports this conclusion. However, descriptions of the deterioration of friction ridge impressions on a metallic substrate submerged in a natural aquatic environment have not been well-documented and an evaluation of the environmental factors has not been thoroughly investigated. Whereas previous studies (Soltyszewski et al., 2007) reported the successful recovery of good to very good quality latent fingerprints after seven days of submergence, this study has shown that after only three days in a natural aquatic environment, friction ridge impressions on a non-porous stainless steel surface were almost completely obliterated. This illustrates the significance of the factors at play in nature. Studies conducted in an aquarium using only tap water, no current, and no macrophyte, or sediment interaction are likely to produce deceptive results in comparison to studies conducted in a more natural environment. Follow-up studies with a higher number of samples may shed light on other factors that affect the success of recovering latent fingerprints submerged in an aquatic environment.

Limitations

Latent fingerprints are often difficult to recover from metal objects as a result of their unusual grainy texture. Although the original texture of the stainless steel blades did not cause difficulty in recovery for this study, there were some areas of the blades that tarnished as a result of their time in the water. These defects occasionally obscured the friction ridge impressions. The tarnishing occurred in equal frequency among items submerged in L1 and L2 and there was no notable difference in tarnishing as the submergence interval increased. The feature that tended to have the most negative effect on the ability to visualize a print was the adherence of sediment on the blade. This phenomenon was most notable on items recovered from L1.While there was no notable increase in sediment cover between Trials 1 and 2, sediment cover was highly prevalent in items recovered in Trial 3.Therefore, it is likely that sediment interaction plays an important role in the deterioration of submerged latent fingerprints. A follow-up study should be performed to remove sediment as a confounding variable.

All waterways are unique and subject to a variety of ever-changing factors, including but not limited to pH of the water, the type or overall presence of aquatic plants and animals, wave interaction, sediment type, current velocity, human interference, temperature and weather. Two nearby sections of the same stream can differ significantly, based only on differences of width and depth (Michaud, 1994; Wetzel, 2001). Therefore, although this study is representative of the effects of similar stream conditions, it does not represent the effects of every stream condition that might be part of a criminal investigation.

The methodical process used to deposit latent fingerprints on the items before immersion was done to ensure consistent print deposition of high quality. Ultimately, the results of fingerprint recovery and visibility scores after being subjected to the various independent variables is partly dependent on the initial quality of the print deposited on the surface. Research has shown that even using a methodical process can result in inconsistent fingerprint deposition (Fieldhouse, 2011). Despite careful vigilance, it is inevitable that “the quantity of force applied, the angle of friction ridge and surface contact and the duration of friction ridge and surface contact” will differ between individual print depositions and result in prints of unequal quality (see Figure 8) (Fieldhouse, 2011, p. 96). To solve this problem in future studies, a device known as a “fingerprint sampler” can be used; this device was specially designed to facilitate fingerprint deposition for research projects (Fieldhouse, 2011).

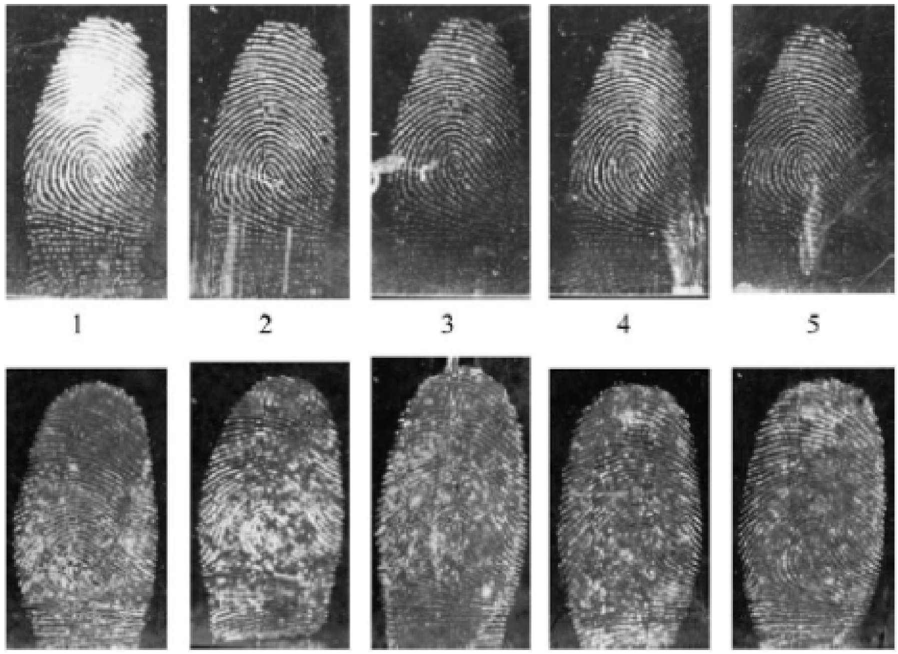

Figure 8: An example of five consecutive fingerprint depositions using a fingerprint sampler (top row) and without a fingerprint sampler (bottom row) (Fieldhouse, 2011)

Cyanoacrylate fuming and powder dusting were the chosen development methods in this study because they are the most commonly used techniques and are fairly versatile in their applicability. However, there are different enhancement techniques that may be more suitable to use on items subjected to the aquatic conditions utilized in this study. For instance, studies by Cuce, Polimeni, Lazzaro, & De Fulvio (2004) and Onstwedder and Gamboe (1989) determined Small Particle Reagent (SPR) to be a successful method for the development of latent fingerprints on wet surfaces. In their research, Onstwedder & Gamboe (1989) determined that SPR yielded more suitable friction ridge impressions than cyanoacrylate fuming followed by powder dusting. Another enhancement technique, vacuum metal deposition (VMD), could be used in replacement of cyanoacrylate fuming, as it is generally considered to be a more sensitive technique. It is especially useful “in instances where latent prints are old or have been exposed to adverse environmental conditions” (Jones, Mansour, Stoilovic, Lennard, & Roux, 2001, p. 167). However, a major disadvantage of the VMD is the high cost associated with its use. Few laboratories own the equipment and those that do use this method sparingly as a result of the expensive materials required (gold and zinc).

Future Directions

Further research is essential to better understand the interactions between friction ridge impressions and the conditions of a natural aquatic environment. This study has shown correlations exist between current velocity and the deterioration of a submerged latent fingerprint. However, additional research is required to evaluate the effect of confounding variables such as sediment interaction. Future research should study the effects of immersion in an aquatic environment on different non-porous objects, such as glass, plastic, or other types of metal. Various types of latent fingerprint processing techniques should be tested to determine which are most successful in visualizing friction ridge impressions that may be wet or obscured by sediment. Diverse aquatic environments, including oceans, rivers, and swimming pools should also be studied to establish the affects of environmental factors such as temperature, current velocity, sediment and macrophyte interaction. Although natural aquatic environments should continue to be utilized in research, controlled aquatic environments in the laboratory should also be employed to study these different factors independently. Finally, various submergence intervals should continue to be tested, since real-life scenarios may involve the recovery of submerged evidence after very long lengths of time.

As the use of recreational waterways continues to increase, so does the incident rate of accidents, drowning, and violent crimes in these areas. Criminals will continue to be drawn to waterways as a place to dispose of incriminating evidence. As a result, law enforcement will continue to be responsible for retrieving articles submerged in water and must be cautious in the handling of these items. The results of this study prove that evidentiary items submerged in water should not be discounted; it may still contain valuable latent fingerprint evidence that may serve as a positive identification of a perpetrator.

This study has shown that in a natural aquatic environment, friction ridge impressions are subjected to a variety of environmental factors that affect the visibility and ultimately the individualizing power of the print. A significant difference in the visibility of friction ridge impressions subject to high current velocity and those subjected to little to no current was observed. Further research in the area of submerged friction ridge impressions is greatly anticipated, as there are many variables yet to be explored.

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