Perils on the High Seas: The Effects of Submersion and Containment on Human Decomposition in Saltwater

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PERILS ON THE HIGH SEAS: THE EFFECTS OF SUBMERSION AND CONTAINMENT ON HUMAN DECOMPOSITION IN SALTWATER

by

Celene Aundrea Sotkowy

A Thesis
Submitted to the Faculty of the Graduate College in partial fulfillment of the requirements for the Degree of Master of Arts Department of Anthropology

Western Michigan University
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Celene Aundrea Sotkowy
Forensic analysis of decomposing human remains in a submerged and contained aquatic environment is an area of research that lacks systematic evaluation and hinders the ability to accurately determine time since death/submersion. Expanding our understanding of how submersion and containment affects the known taphonomic agents pursuant to aquatic environments will contribute to the knowledge base on human decomposition in a multitude of environments.

In response to this limited knowledge base, this thesis reviews ten marine and air incidents occurring along the coast of British Columbia, Canada in which the bodies of eighteen individuals were recovered from inside the submerged wreckage of ships, aircrafts, and automobiles to ascertain if the microenvironment contained within the vessels alters known taphonomic agents. This thesis also looks at leaked fuel as a potential taphonomic agent that has been previously overlooked in the published literature. Although the information garnered here is limited, it will contribute to the discussion of human decomposition in a multitude of environments.
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CHAPTER I
INTRODUCTION

When conducting an assessment of decomposition of human remains, analyzing the forensic taphonomy allows anthropology to understand how the taphonomic agents present in the environment act upon the corpse. Forensic taphonomy is the postmortem analysis of the human body from the moment of death to recovery and includes an assessment of the multitude of taphonomic agents which play a role in the disintegration and dispersal of body parts throughout the environment (Haglund and Sorg et al. 1997).

Taphonomic agents can occur naturally in the environment and include ambient temperature and animal predation. Other agents are introduced by human activity and include chemicals or fuels. All agents have some degree of effect on decay rates and will determine how decomposition is exhibited on the corpse (Cotton et al. 1987; Haglund and Sorg, 2002; Rodriguez, 1997); whether it be putrefaction, mummification, skeletonalization, or adipocere formation (Bassett and Manhein, 2002; Haglund 1993; Kahana et al. 1999; Petrik et al. 2004; Sorg et al. 1997; Rodriguez 1997; Wentworth et al. 1993).

Understanding the relationship between the taphonomic agents specific to the environment and human decomposition patterns is vital to the recreation of the postmortem history for any recovered human remains. While forensic science’s understanding of this relationship in many terrestrial environments is significant, the effect of taphonomic agents on human decay patterns in aquatic environments is considerably less understood (Anderson and Hobischak, 2004; Hobischak, 1998; Merritt and Wallace, 2001; Petrik et al. 2004).
This lack of understanding is true for the aquatic environments of British Columbia, Canada. Considering that the Chief Coroner’s Office reported 32 water related deaths in British Columbia in 2006, 49 in 2005, and 56 in 2004 (Wallace-personal communication, 2007), it is paramount that forensic anthropology continues to examine and understand the relationship between taphonomic agents and human decay patterns to be able to accurately assess the decomposition rates for human remains recovered from a multitude of aquatic environments.

Therefore, the aim of this thesis is to examine decomposition rates of human remains, in three different man-made vessels (ship, aircraft, and automobile) all submerged in the marine environment of British Columbia to determine the taphonomic processes that retard or accelerate human decay rates. In the course of this examination, this thesis will explore how new taphonomic agents specific to submerged vehicles are introduced to the postmortem environment, but are often ignored in many of the case studies reviewed. Specifically, how the introduction of leaked fuel into the surrounding water could potentially alter human decomposition rates and hinder the action of other taphonomic agents.

Considering that subtle changes in the environment have been shown to cause variations in the types of taphonomic agents present (Anderson and Hobischak, 2004, Rodriguez, 1997; Simonsen, 1977), it is reasonable to propose that the microenvironment inside a submerged vehicle will produce a taphonomy that is slightly different from the taphonomy produced in other aquatic microenvironments. This change may be enough to alter the decay patterns for sequestered human remains from the patterning commonly associated with human bodies recovered from the open water.
Therefore, the findings of this thesis will be compared with the existing literature on human remains recovered from open and contained aquatic environments to facilitate a discussion on how the presence or absence of some taphonomic agents will influence the decomposition patterning of the submerged human remains. Information garnered from this research will provide a limited understanding of the decay process in enclosed submerged environments off the coast of British Columbia. Considering that many police agencies work closely with and rely on the research provided by physical anthropology, it is vital that anthropologists continue to contribute to the field of forensic science by providing data which aids in the recreation of the postmortem history of any recovered human remains. By doing so, forensic anthropology will be able to develop normative standards for the assessment of time since death/submersion and contribute to the overall understanding of human decomposition in any environment.

To complete the goal of this thesis, one must first determine which taphonomic agents are commonly associated with aquatic environments. This information will be provided in the form of a literature review in Chapter Two and will include an overview of the multitude of water environments from which human remains have been recovered. Emphasis will be placed on how human remains interact with a water environment, i.e. descent and ascent in the water column, and drift in the current, and how specific taphonomic agents encourage specific decay patterning, i.e. colder ambient temperatures encourage adipocere formation whereas animal predation encourages skeletalization.

Chapter Three outlines the reviewed coroner inquests and autopsy reports from the British Columbia Coroner’s Office and the marine and air reports from the Transportation Safety Board of Canada (TSB) to examine the decompositional variables
noted on the human bodies and which taphonomic agents were present in the vessels’
environments. Chapter Four provides a discussion on the analysis of the coroner inquests,
autopsy reports, and safety reports to create an overview of the postmortem history for
the sequestered human remains.

Through the synthesized review provided in Chapter Two and the analysis in
Chapter Four, the background necessary to understand the relationship between aquatic
taphonomic agents and human decay patterns will be provided to illustrate the necessity
for additional empirical studies to be conducted to examine submersion and containment
factors on human decomposition in any aquatic environment.

In conclusion, Chapter Five provides a discussion of the implications this thesis
has within the larger forensic sciences’ audiences. Particularly, why it is important that
forensic anthropology develop a normative standard of collecting data pertinent to the
determination of time since death and why it is important that forensic science tries, to
the best of human ability, to treat an aquatic death scene with the same detailed analysis
as a terrestrial one. Only when normative standards on data collection are developed will
the relationship between taphonomic agents and human decay rates be fully understood to
the extent that an accurate assessment of decomposition and the recreation of the
postmortem history of human remain recovered from a multitude of aquatic environments
can be conducted.
CHAPTER II

THE TAPHONOMY OF HUMAN REMAINS IN AQUATIC ENVIRONMENTS

The goal of this chapter is to utilize the published literature which examines the taphonomy of human remains submerged in a multitude of aquatic environments to facilitate a discussion on human decay patterns. Having insight into the known literature will demonstrate areas of research that have been explored, as well as allowing for a discussion on areas that have received less attention. In doing so, forensic science can begin to address the limitations in the published literature.

To aid in a well rounded discussion, this chapter will be grouped into three sections. First, an overview is provided on how a human body is able to move in an aquatic environment. This movement includes descending and ascending in the water column, transportation by current activity, and beaching along the shore. In addition, this section will discuss how disarticulated body parts move differently in the current than an articulated human body.

Second, an overview of human decomposition in aquatic environments is provided. Comparisons will be made between the stages developed for submerged events with those developed for semi-aquatic events where terrestrial taphonomic agents play a significant role in decompositional patterning. Included in this section will be an introduction of fuel leakage as a possible aquatic taphonomic agent which appears to have been overlooked by most of the published literature.

Third, this section will conclude with a discussion of the limitations in the published literature. Specifically, how the development of decompositional stages for
fully submerged and confined human remains have received less attention then those developed in semi-aquatic environments.

2.1 Submerged Human Remains in Aquatic Environments

Water is three dimensional which allows the human body to interact with the environment in a way that is not seen on land. A submerged body will slowly sink to the bottom, gently float at the surface, or be violently tossed against rocks and other obstacles in the water (Boyle et al. 1997; Dilen, 1984; Haglund and Reay, 1993; Nawrocki et al. 1997; Skinner et al. 1988). The body can be transported great distances in current driven environments (Brooks and Brooks, 1997; Giertsen and Morild, 1989; Jaffe, 1999; Nawrocki et al. 1997) or beached at irregular intervals along the shore during low tide (Ebbesmeyer and Haglund, 1994, 2002; Jaffe, 1999). Knowing how and where a submerged human body has been transported is vital to understanding the postmortem history because the taphonomic agents present in the environment will influence the type of decompositional patterning on the human remains and the extent to which isolated body parts can be dispersed throughout the water system.

2.2 Descent and Ascent of the Body in the Water Column

A living person entering the water has a tendency to float due to the air contained within the lungs, the cells of the body, and in the clothing (Boyle et al. 1997; Donoghue and Minnigerode 1977; Haglund and Sorg, 2002). Trapped air acts as a natural flotation device which maintains the body’s natural positive buoyancy. Objects having positive buoyancy will float. In contrast, a deceased person immersed in water will have negative
buoyancy due to the lack of inhaled air trapped in the lungs and cells of the body. As a result, the human body becomes denser and develops a heavier specific gravity which displaces the surrounding water and allows the body to descend to the lower depths (Boyle et al. 1997; Dilen, 1984; Donoghue and Minnigerode 1977; Haglund and Sorg 2002; Nawrocki et al. 1997; Petrik et al. 2004; Rodriguez, 1997).

As the human body descends, atmospheres of pressure are exerted on it. One atmosphere is calculated to be 33 pounds per square inch (PSI) (Dilen, 1984; Donoghue and Minnigerode 1977; Gambicourt-personal communication, 2006; McFarlene-personal communication, 2006; Teather, 1994). At the surface level, there is one atmosphere of air pressure exerted. As the human body descends, more atmospheres of water pressure are exerted for every ten metres of water. Therefore, at ten metres below the surface, there is a total of two atmospheres exerting pressure on the human body, one atmosphere of air and one atmosphere of ten metres of water. At twenty metres, there are three atmospheres, one atmosphere of air and two atmospheres of water. The number of atmospheres exerting pressure on the body will continue to increase the lower the body descends (Dilen, 1984; Donoghue and Minnigerode 1977; McFarlene-personal communication, 2006). The deeper the body descends, the faster it will descend. The compounded atmospheres compress any residual air contained in the clothes, lungs, and cells. The human body becomes denser and displaces more water (Boyle et al. 1997; Dilen 1984; Donoghue and Minnigerode 1977; Teather, 1994; Tomita 1975).

Until buoyancy changes, a body will remain along the bottom and only rise when the force of lift is strong enough to start the ascent (Dilen 1984; Donoghue and Minnigerode 1977; Haglund and Sorg 2002; Nawrocki et al. 1997; Rodriguez. 1997;
Tomita 1975). It is possible for the ascent to be initiated by a build up of decompositional gases produced during the bloat stage (Boyle et al. 1997; Haglund and Sorg 2002; Petrik et al. 2004; Rodriguez, 1997) or by up-lifts from undercurrents (Dilen, 1984).

The processes that push a body down will work in reverse to lift the body up. That is, as the body rises, fewer atmospheres are exerting pressure which allows the expansion of any residual air contained within the lungs and cells of the body. The human body becomes less dense. As the body gets closer to the surface, the faster it will rise (Dilen, 1984; Donoghue and Minnigerode 1977; Haglund and Sorg, 2002; Nawrocki et al. 1997; Teather, 1994).

In situations where a deceased person submerges to depths deeper than 18 metres, the chances of that body rising and breaching the surface are reduced (MacFarlane-personal communication, 2006; Tomita, 1975). The compounded atmospheres exerted at those depths produce an external pressure that is greater than the internal pressure caused by the build up of decompositional gas (MacFarlane, 2006). The compounded pressures compress the residual air in the cells of the human body to a degree that the bloat stage may not be initiated and the human cells are unable to expand with decompositional gas (MacFarlane, 2006). The lack of gas buildup in the body fails to produce a force of lift that is able to over come the compounded atmospheres of pressure which causes the body to remain submerged in the deeper depths.

The rate and final depth of the descent is highly variable and dependent upon the types of taphonomic agents present in the aquatic environment. Taphonomic agents include trapped air and ambient temperature. Wearing a personal floatation device (PFD) will hinder the descent of a body (Ebbesmeyer et al. 1991a), as will a large volume of air
trapped within clothing (Anderson and Hobischak, 2004; Boyle et al. 1997; Dilen, 1984; Haglund and Sorg, 2002; Petrik et al. 2002; Sorg et al. 1997). Trapped air will cease to be a taphonomic agent if the body is stripped of clothing or the material becomes saturated, ripped, or deteriorated (Boyle et al. 1997; Dilen, 1984; Haglund and Sorg, 2002; Sorg et al. 1997).

Ambient temperature is an important taphonomic agent because it directly determines the duration of time a body remains submerged. In warmer months, any aquatic environment having a temperature greater than 10° Celsius will have the ideal conditions necessary for the production of decompositional gas (McFarlane, personal communication, 2006). A body will often resurface within a few days to a couple of weeks, (McFarlane, personal communication, 2006; Rodriquez, 1997; Tomita, 1975). During the colder months, temperatures below 8° Celsius will practically arrest the bacterial action necessary to the ascent process (Jaffe, 1999; Tomita, 1975). The human body will remain submerged for several weeks to several months (McFarlene-personal communication, 2006; Rodriquez, 1997; Tomita, 1975). When water temperatures rise above 8° Celsius decomposition will resume and the ascent process will be initiated.

Similarly, temperature levels associated with varying water depths have the same affect as seasonal temperatures. Even in the warmer months, the temperature below a depth of 30 metres can reach refrigerator-like conditions. If the decomposition gas buildup is not produced, the human body is unable to bloat and ascend to the surface (Gambicourt-personal communication, 2006; Jaffe, 1999 McFarlene-personal communication, 2006; Tomita, 1975).
The relationship between water depth, temperature, and decompositional gas buildup is evident in the case studies provided by Tomita (1975). In the review of several marine disasters occurring along the coast of Japan from 1955-1961, Tomita (1975) determined that submerged human bodies often resurfaced within 3 days when water temperatures are at or above 20° Celsius and at depths between 10 to 30 metres; but only as long as the human bodies did not come into contact with the mud or sandy bottom substrate. Contact with the bottom substrate allowed local marine animals to scavenge the human bodies or became weighed down with a covering of mud. In events where the human bodies sank to depths greater than 50 metres, the excessive pressure exerted hindered any decompositional gas buildup so the bodies could not bloat. When the marine disasters occurred in coastal areas having a water temperature of less than 15° Celsius, the submerged bodies took several weeks to several months to resurface. In many of these disasters, some human bodies were never recovered.

2.3 Body Transport in Current Driven Environments

In a current driven environment, the human body will be transported away from the point of entry (Bassett and Manhein, 1997; Brooks and Brooks, 1999; Dilen 1984; Ebbesmeyer et al. 1991a,b; Ebbesmeyer and Haglund, 1994, 2002; Tomita, 1975). The distance transported is highly variable and dependent upon whether the water system is a lentic (stagnant) or a lotic (current driven) environment (Bassett and Manhein, 1997; Brooks and Brooks, 1999; Dilen 1984; Ebbesmeyer and Haglund, 1994, 2002; Tomita, 1975). Understanding the fluvial dynamics of any aquatic system is useful to the
recreation of the postmortem history as it provides information on the taphonomy of the human remains.

In lentic systems, such as a small lake environment, the general rule is that for every metre down a body sinks; it will drift the same distance away from the point of entry. That is, if a body sinks 10 metres down in the water, it will drift 10 metres away from the point of entry (Gambicourt-personal communication, 2006; McFarlene-personal communication, 2006; Teather, 1994).

In lotic systems, such as in rivers or oceans, the distance traveled is dependent upon the fluvial dynamics of the environment which include the strength and route of the current, the characteristics of the substrate, and the presence of any impediments in the environment (Dilen, 1984; Ebbesmeyer et al. 1991a,b; Ebbesmeyer and Haglund, 1994, 2002; Giertsen and Morild, 1989; Tomita, 1975). There are several examples in the published literature of human bodies transported great distances in current-driven systems. Giertsen and Morild (1989) describe two situations where Danish nationals were found floating in the Norwegian Sea nearly 500 kilometres from their original points of entry. It was assumed that both men were transported by the Gulf Steam. Ebbesmeyer et al. (1991a,b) were able to determine that the victims of the 1875 sinking of the *SS Pacific* were transported within well-defined drift routes, some of which were 100 kilometres in length.

In a study of the fluvial dynamics of the Chattahoochee River, Dilen (1984) immersed two manikins into the river current to identify behaviours indicative of floating and submersion events which could be exhibited by humans under similar circumstances to determine if there are similarities with the two events. The floating research showed
two different behaviours depending on where in the river the body was dumped. First, there is a tendency for an immersed body to remain along the same side of the river that it entered due to the movement of the current. Second, a human body dropped in the centre of the river will travel farther downstream than one immersed along the side due to a lack of impediments.

The submersion research showed that a submerged human body is not transported as far as floating remains. In the case of the Chattahoochee River, the undercurrents may not have had the strength to move a body or there may have been too many impediments on the bottom substrate on which the body snagged.

Bassett and Manheim (2002) analyzed how the fluvial mechanisms found in the Mississippi River transport human remains and came to similar conclusions as Dilen (1984). Bassett and Manheim (2002) looked at the relationship between an immersed body, duration of immersion, and fluvial dynamics of the Mississippi River. Through their research they were able to determine that river currents will work to keep an immersed human body to the same side of the river that it entered in on and that longer immersion periods result in greater distances traveled.

When body transport occurs in oceans, channels, or straits, there is the potential for a submerged human body to be beached on shore. If beached, the body will remain on land until water levels increase with high tide and re-float the body back out to open water (Ebbesmeyer and Haglund, 1994, 2002; Jaffe, 1999). Under these circumstances, a body can go through several cycles of floating, beaching, and re-floating before being found (Ebbesmeyer and Haglund, 1994, 2002; Haglund and Sorg, 2002; Nawrocki et al. 1997).
Ebbesmeyer and Haglund (2004) provide an account of a fatal bridge-jump in which the body of an adult male was recovered 32 kilometres away from the original point of entry. Taking into consideration the time of the jump, first sighting, recovery location, tidal information, and outflow from the adjoining rivers, the reconstruction was able to propose two possible scenarios. The first scenario proposed that the body was transported in a direct route to where it was beached and eventually recovered. In the second scenario, the body may have undergone a cycle of beaching and re-floating at several locations before being recovered. The implication here is that while beached, the body or portions of it will be exposed to terrestrial taphonomic agents, such as warmer ambient temperature and various terrestrial scavenging species. Terrestrial agents are known to accelerate decay rates which can cause exposed portions of the body, typically the head and upper torso region, to reach a skeletal state while the lower body region is still in the bloat stage of decomposition (Nawrocki et al. 1997; Teather, 1994). The advanced stages of decomposition on the terrestrial-exposed regions of the body may cause the duration of the submersion period to be over estimated. Also, the upper body region may separate from the torso while the lower limbs remain attached, thus affecting how the body will be transported (Nawrocki et al. 1997).

Disarticulated body parts and isolated bones do not transport in the same way an intact human body will due to the loss of soft tissue which results in a reduction in surface area and density (Nawrocki et al. 1997). Separated limbs have less buoyancy than the torso region due to the lack of decompositional gas buildup and are less likely to resurface. As the disarticulation becomes more pronounced, the torso region will also lose much of its buoyancy and sink down again (Haglund, 1993; Nawrockie et al., 1997).
The transportability of isolated bones varies significantly depending on the shape and condition of individual bone. Nawrockie et al. (1997) categorized isolated bones into three groups depending on how easily they are transported in the current. First is the “transport” group of bones which are easily transported in the current. These bones tend to be small, round, and less dense than other bones in the body. Ribs, vertebrae, sacrum, and sternum fall into this category. Second is the “lag” group. These bones are prone to sinking and are not easily transported. They are flat and denser than other bones. This group includes the mandible. Third is the “intermediate” group. These bones are less resistant to transportation than the lag group and include long bones, phalanges, pelvic, and scapulae.

The concern here is that separation disperses the body over a large area so that isolated body parts and bones belonging to one individual may be recovered over a period of time and from different locations. Darok et al. (2005) describe how scuba divers recovered a cranium and several long bones from a lake in Austria. A humerus and shoe with foot bones had been discovered from the same lake years earlier. Following the M/S Estonia ferry disaster off the coast of Finland, Soomer et al. (2001) report the recovery of three long bones and one skull belonging to several of the victims, 18 months after the accident. Haglund and Reay (1993) document a case of an articulated foot and lower leg that were recovered two weeks before the rest of the body. Skinner et al. (1988) provide an account of an isolated mandible recovered two years after the owner had been identified. As of June 2008, five separate shoes containing feet have been found at different locations along coastal British Columbia. The Royal Canadian Mounted Police are currently conducting investigations to identify the individuals to whom these feet
belong (Lazaruk, 2008). The primary concern with all of these cases is that, as a result of the disarticulation and dispersal of individual body parts and bones over a potentially larger area, valuable time and resources may be spent on identifying someone who has already been found by investigators (Haglund and Reay, 1993; Skinner et al. 1988).

2.4 Human Decomposition in Aquatic Environments

Several decay types can present on the human body and include putrefaction, mummification, skeletalization, and adipocere formation (saponification). This section will focus on putrefaction, skeletalization, and adipocere formation as they are known to present in aquatic environments. Mummification is not included as it tends to occur in hot, dry terrestrial environments.

Putrefaction is often associated with the early stage of decomposition and is basically defined as the disintegration of the soft tissue caused by the body’s natural bacteria turning against the body (Jaffe, 1999). Bloating is the bi-product of this bacterial action and is caused as the decompositional gas in the gastro-intestinal system builds up. As the body bloats, facial features and torso region can distort to the extent that visual identification is impossible (Dix and Graham, 2000; Jaffe, 1999). Gradually the bloating subsides and the body begins to liquefy. Depending on conditions in the environment, putrefaction can remain up to 6-8 weeks (Jaffe, 1999).

In water, the onset of putrefaction depends on the temperature and salinity levels of the environment. Tropical water temperatures encourage soft tissue to liquefy and macerate so the rate of soft tissue loss will be rapid (O’Brien 1997; Merritt and Wallace, 2001; Petrik et al. 2004). Temperate water temperatures retard soft tissue loss, thus
maintaining the human body in a relatively good state of preservation (Dix and Graham, 2000; Jaffe, 1999; Petrik et al. 2004). Putrefaction tends to be slower in salt water than fresh because higher salinity levels hinder the bacterial growth necessary for the production of decompositional gases that result in the bloat stage (Boyle et al. 1997; Petrik et al. 2004; Rodriguez, 1997).

Skeletalization is the type of decay associated with more advanced stages of decomposition. Basically, the soft tissue loss is so advanced that the remains are reduced down to the skeletal state (Jaffe, 1999). Soft tissue loss is due to the passage of time or animal predation. Depending on the taphonomic agents present in the environment, both putrefaction and skeletalization can present on the body at the same time.

The most common decay type noted on submerged human remains is adipocere formation (Anderson and Hobischak 2004; Boyle et al. 1997; Cotton et al. 1987; Dix 1987; Merritt and Wallace, 2001; Petrik et al. 2004; Pfeiffer et al. 1998; Rodriguez, 1997; Rothschild et al. 1996; Sorg et al. 1997). Adipocere is a waxy substance produced as a bi-product of hydrolysis and hydrogenation of adipose tissue (body fat) and fermenting bacteria (Cotton et al. 1987, Dix, 1987; Dix and Graham, 2000; Jaffe 1999; Mellen et al. 1993; Rothschild et al. 1996; Simonsen, 1977; Yan et al. 2001). The formation occurs when the fats are converted into palmitic and stearic acids (Yan et al. 2001).

Water temperature, current flow, clothing, and the amount of exposed soft tissue often determine if and where adipocere will form on the body (Kahana et al. 1999; O’Brien, 1997; Mellen et al. 1993; Yan et al. 2001; Simonsen, 1977). Some researchers report seeing adipocere formation within a few weeks of submersion (Kahana et al. 1999; Simonsen 1977; Tomita, 1975), while others have noted it may take several months
(Lewis et al. 2004; Petrik et al. 2004) to a couple of years (Cotton et al. 1987; Uchigasaki et al. 1995) to completely encase a body.

Once formed, adipocere is virtually indestructible and can last for many years under proper conditions (Dix and Graham, 2000; Jaffe, 1999; Kahana et al. 1999; Rodriguez, 1997; Simonsen, 1977). Cotton et al. (1987) examined the adipocere formation on two bodies that were submerged in 30 metres of water for five years. Adipocere had developed in anatomical regions, including neck, face, torso, and limbs; but was not present in the peritoneal or thoracic cavities. All internal organs were present; including the brain which had a soft, paste-like texture to it. These researchers concluded that adipocere encased the body like an outer shell, preserving the internal organs to such a high degree that the anatomic features were visible and recognizable.

The different decay types coincide with the different stages of decomposition a human body may progress through. Decomposition stages for terrestrial environments are well documented and clearly defined. They include fresh, bloat, active decay, advanced decay, and skeletonized. Although slightly modified, decomposition in aqueous environments also progresses through five stages and includes submerged fresh, bloat/float, active decay, advanced decay, and sunken/skeletal remains (Anderson and Hobischak, 2004; Davis and Goff, 2000; Haskell et al. 1989; Hobischak, 1998; MacDonell and Anderson, 1997; Merritt and Wallace 2001; Payne and King, 1972; Petrik et al., 2004). It should be noted that the research leading to the development of these stages was based in semi-aquatic environments where terrestrial insect species still had some access to the body (Anderson and Hobischak, 2004; Davis and Goff, 2000; Haskell et al., 1989; Hobischak, 1998; Hobischak and Anderson, 2002; MacDonell and Anderson,
1997; Merritt and Wallace 2001; Payne and King, 1972). This reliance on terrestrial entomology for the development of decompositional stages for immersion events is evidence of the lack of systematic research being conducted in fully submerged environments. According to Anderson (personal communication, 2007), descriptions of human decomposition occurring purely in a submerged environment, in which the body is exposed to the open water but where terrestrial variables are not a factor, are in the preliminary stages of research.

Two research studies were found which examined decompositional stages for submerged remains in British Columbia. In Hobischak’s (1998) examination of freshwater aquatic invertebrate succession, eight pig carcasses were submerged in lotic and lentic systems inside the Knapp Research Facility, British Columbia. Exposure to terrestrial taphonomic agents occurred with some of the pig carcasses when water levels resided. For both lotic and lentic systems, the time frame for each decompositional stage ranged from 11 to 13 days for the fresh stage, 23 to 37 days for bloat, 0 to 324 days in decay, 0 to 228 days in post decay, and 0 to 331 days in sunken remains stage. Hobischak determined that decomposition was delayed in both water systems when compared to local terrestrial results due to colder ambient temperatures and lack of terrestrial maggot masses.

In another experiment, Anderson and Hobischak (2004) submerged six pig carcasses at two depths, 7.6 metres and 15.2 metres, in the marine environment of British Columbia. These depths excluded any terrestrial agents from influencing the decomposition rates. The pigs were tethered so they could freely move in the water
column but not able to float away and breach the surface. The researchers noted the following decompositional changes. See Table 1.

Table 1. Stages of Decomposition in Fully Submerged Environments – Derived from Anderson and Hobischak (2004).

<table>
<thead>
<tr>
<th>Stage of Decomposition</th>
<th>Decompositional Characteristics Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submerged Fresh</td>
<td>Body descends in water column. Immersion changes, rigor mortis and lividity are noticeable.</td>
</tr>
<tr>
<td>Bloat/Float</td>
<td>Buildup of decompositional gases in the gastrointestinal tract start the ascension process. Discolouration and marbling are noticeable in the soft tissue.</td>
</tr>
<tr>
<td>Active Decay</td>
<td>Skin and body hair start to slough off. Soft tissue begins to lose its integrity. Bloat still noticeable.</td>
</tr>
<tr>
<td>Advanced Decomposition</td>
<td>Significant soft tissue loss. Adipocere formation is noticeable on the body. Facial area and limbs can be partially skeletonized. Disarticulation and dispersal of smaller body parts occurs.</td>
</tr>
<tr>
<td>Remains</td>
<td>Due to significant lose of soft tissue and the release of decompositional gases, the body settles back down to the bottom substrate.</td>
</tr>
</tbody>
</table>

The stages of submersion decomposition as outlined above by Anderson and Hobischak (2004) are explored further here. Submerged fresh is the initial immersion and descent in the water and coincides with the early stage of putrefaction. This stage has a duration period of up to three days. Immersion changes or washer woman’s hand (wrinkling of the skin on palmer surfaces), rigor mortis, and livor mortis are present on the carcasses. In the bloat stage decompositional gases have expanded in the intestines causing the carcasses to bloat and ascend in the water column. Discolouration and
marbling are noticeable in the soft tissue. This stage was still noticeable more than two weeks after its initial appearance. In the active decay stage, the soft tissue is beginning to lose its integrity and bloating is still noticeable. This phase is still noticeable more than a month following its initial appearance. The advanced decomposition stage exhibited loss of skin, soft tissue, and body hair (loss of the epidermis) and coincides with the early phase of skeletalization. Adipocere formation is noticeable on the carcasses. The skull and areas containing less tissue, such as the limbs and joint areas, are starting to skeletonize. Disarticulation and dispersal of body parts occurs during this stage. There was no clear delineation between active decay and advance stages. In the remains stage, adipocere was noted after 47 days. Skeletalization was advanced, yet one of the carcasses continued to float due to decompositional gas. The other remains settled back down to the bottom substrate due to a substantial loss of soft tissue and gas buildup.

Anderson and Hobischak (2004) noted that only the fresh and skeletonized stages were easily distinguishable on the submerged carrion even though all of the decompositional traits associated with submersion were noted throughout the experiment. All other stages were less discreet and overlapped one another. The analysis revealed that trapped gas in the intestines of the pig carrion extended the bloat stage even though most of the carcasses were nearly skeletonized. Anderson and Hobischak’s (2004) concluded that decompositional stages are not as clearly defined in aquatic environments as in semi-aquatic. Their conclusion supports their findings from a previous case study examining human decomposition in fresh water environments. In this case study, Hobischak and Anderson (1999) conducted a review of coroner cases pertaining to freshwater deaths occurring from 1995-1996 in British Columbia to determine if postmortem changes were
reliable indicators of time since submersion. The study examined 47 cases in which the time since submersion ranged from 5 days to 4 years. A list of immersion characteristics associated with each stage of decomposition was developed from the general descriptions provided in the coroner cases. The characteristics included washer woman’s hands, bloat, marbling, discolouration, skin sloughing, hair shredding, tongue protuberance, body fluid leakage, odor, postmortem scavenging, adipocere formation, skeletalization, algae formation, marine invertebrates, and silt. Washer woman’s hands were present on the bodies for the first 12 days, skin sloughing appeared between 5-120 days, and discolouration was present between 3-91 days. Clearly these findings do not conform to expected patterns of decay. It has generally been believed that these immersion changes occurred during limited timeframes. For example, washer woman’s hands were believed to be noticeable during the first three days following immersion and skin sloughing would occur over the first two weeks (Jaffe, 1999). Once this period of time ended, the body was thought to enter into the next stage of decomposition where another set of decompositional characteristics would become apparent.

Anderson’s and Hobischak’s (1999) results suggest that immersion changes, especially those occurring during the early postmortem period, do not appear in a predictable manner and as such, may not be reliable indicators for the development of time since submersion models. This unpredictability has contributed to the myriad of factors present in each of the environments examined, a limited knowledge base regarding decomposition patterns in aqueous environments, and the lack of detailed descriptions provided in the coroner’s findings. These researchers advocate for more
detailed and consistent reporting by investigators and continuing research in this area before time since submersion models can be accurately developed.

A similar review of human decomposition in freshwater environments was conducted by Petrik et al. (2004). The researchers examined seven video files dating from 1995-2003 that were provided by the Canadian Amphibious Search Team (CAST) and five cases dating from 1998-2000 that were provided by the British Columbia Coroner’s Office. Unlike the previous case review by Hobischak and Anderson (1999) Petrik et al. (2004) review specifically examined the environmental differences found in each of the freshwater habitats a body was recovered from to understand how the environmental differences affected decompositional patterns. Differences in the decomposition patterns were attributed to differences in the types of habitats, water temperature, and scavengers. The habitats consisted of lotic and lentic systems. In the lotic systems, which consisted of a waterfall and several rivers and streams, turbulent movement in the currents resulted in rapid soft tissue degradation due to the scraping and banging against the rocky bottom substrate and other obstacles. The slower movement in the lentic environments did not create postmortem artifacts seen in the lotic systems. Biological degradation was present in both lotic and lentic systems.

Sudden and unexpected environmental changes have been shown to alter the decay patterning of immersed human remains. In an unusual case involving a body of an adult male that washed ashore on a small Danish island in the North Sea, Simonsen (1977) noted that the level of adipocere formation on the body was representative of an extended period of submersion. Based on the degree of adipocere formation, investigators initially placed the submersion period to be between 3-6 months. The ensuing
investigation determined the body belonged to a pilot who died in a plane crash that occurred 22 days before the body was found. An examination of the air and water temperatures revealed the area had experienced unusual climatic conditions that were more suitable for rapid adipocere formation than that is typically seen in the area.

In a ship wreck or other mass immersion events, rescue divers have noted that recovered human remains will exhibit different stages of decomposition from one another even though they are retrieved from the same enclosed environment. Kahana et al. (1999) research presents a series of thirteen bodies recovered from inside the Mineral Dampier which sank in the East China Sea. Nine bodies were recovered from the middle deck in 65 metres of water. Water temperature ranged between 10-12° Celsius. Duration of submersion ranged from 25-68 days. The most noted decompositional traits were bloating, extensive marbling, discolouration of the face and abdomen regions, skin slippage around the hands and feet, loss of body hair, and liquefaction of internal organs. A thin crumbly layer of adipocere was present on the face and torso regions. These nine bodies were determined to be in between the bloat-active decay stages of decomposition.

The final four bodies were recovered fifteen months following the submersion event from the lower deck in 80 metres of water. Temperatures at this level remained at 10° Celsius. Three of the bodies were found in an open cabin and were completely skeletonized. Skeletalization was attributed to the strong current flow in that location of the ship which may have accelerated the soft tissue loss. Even though numerous crustaceans were reported around the hull of the ship, marine predation was ruled out as the cause of the skeletalization as none were found with the remains. The fourth body, found in a closed
cabin, was completely covered in a hard and crumbly crust of adipocere. The authors believe the lack of current in this cabin facilitated the developed of adipocere.

Kahana et al. (1999) concluded that the decomposition rates noted in this submersion event do not support the published literature. The cold water temperatures significantly retarded the onset of putrefaction. Also, the hull of the ship trapped the individuals so when they entered the bloat stage, they were unable to ascend to the surface level. Being trapped may have delayed the progression into the later stages of decomposition by denying any exposure to the terrestrial environment. As a result, adipocere formation, and not skeletalization, was the dominant type of decay presented in this series.

In another mass submersion event, nine crewmembers perished when the *Ehime Maru* sank after being struck from below by the USS *Greenville* (Lewis et al. 2004). The ship lay at a depth of 610 metres where water temperature was reported between 5-6°C. Due to the inherent danger associated with working at this depth, the ship was moved to a depth of 35 metres where the water’s temperature was 25°C. Following a submersion period of eight to nine months, seven intact bodies and one partially intact body were recovered from inside the ship. One body was never recovered. Decompositional stages varied and ranged from early to advanced. Adipocere was noticeable on the internal organs of six of the crewmen. The seventh crewmember’s chest was completely skeletonized and missing the internal organs. Since water temperature was estimated to have been constant throughout the ship, Lewis et al. (2004) could not determine a cause for the differences in decompositional stages seen on the bodies.
2.5 Marine Scavenging

Another factor influencing the decompositional patterning in aquatic environments is marine scavenging. The dominant scavengers are from the Phylum Arthropoda, with crustaceans being the most voracious feeders. Crustaceans include various species of crayfish, lobsters, crabs, prawns, shrimps, and a family of invertebrates referred to as sea lice (Anderson and Hobischak, 2004; Boyle et al. 1997; Haglund and Sorg., 2002; Hobischak, 1998; Merritt and Wallace, 2001; Petrik et al. 2004; Rodriguez, 1997; Sorg et al. 1997; Teather, 1994). Other species known to scavenge submerged carrion are cod, salmon, whelk, star fish, turtle, and shark (Boyle et al. 1997; Merritt and Wallace, 2001; Petrik et al., 2004; Rodriguez, 1997; Sorg et al. 1997).

Crustaceans have evolved functionally to specialize in the consumption of submerged carrion and are well equipped to find and consume any corpse submerged in their territory (Anderson and Hobischak, 2004; Boyle et al. 1997; Haglund and Sorg, 2002; Merritt and Wallace, 2001; Petrik et al. 2004; Rodriguez, 1997; Sorg et al. 1997; Teather, 1994). Fields of forensic science which include anthropology and entomology are being used to examine faunal scavenging behaviours to see if the colonization of submerged carrion occurs in a predictable manner that will allow for the development of time since death/submersion timeframes (Anderson, 2008). If predictable timeframes can be developed, crustaceans may become the ideal indicators species in the determination of time since submersion of human remains, similar to the way terrestrial insects are used on land.

Larger species of crustaceans like lobsters, crabs, crayfish, and prawns are capable of creating trauma similar in appearance to cut marks (Anderson, 2008;
Rodriquez, 1997; Sorg et al. 1997; Teather, 1994). This feeding action accelerates decomposition by tearing open the soft tissue, creating openings for smaller crustaceans to access (Sorg et al. 1997). These larger species are capable of reducing a submerged human body down to a skeleton within a few days (Petrik et al. 2004; Skinner et al. 1988; Teather, 1994). Salt-water shrimps, the smallest of the crustaceans, can de-flesh a human body within twelve hours due to their shear population numbers (Teather, 1994). Crustacean scavenging can continue even after the body has washed ashore (Petrik et al. 2004).

Many fish species are often the first to arrive at any floating body (Sorg et al. 1997). Larger fish species, such as cod, salmon, and pike are capable of inflicting significant postmortem trauma (Giertsen and Morild, 1989). They rip away the skin to gain access to the vital organs, often leaving large holes in the body (Sorg et al. 1997). This action quickly disintegrates the soft tissue and allows smaller aquatic species to access the body by entering the holes left by the larger fish or consuming the bits of flesh dropped during the scavenging process (Sorg et al. 1997).

This type of feeding behaviour was noted by Anderson (2008). Anderson, in collaboration with the Victoria Experimental Network Under the Sea (VENUS) submerged a pig carcass to a depth of 94 metres in the Saanich Inlet of coastal British Columbia. A remotely operated underwater digital video camera was used to monitor local faunal feeding behaviours on the carcass. On Day 2 of the submersion period, a large section of rear left flank had been removed. The analysis of the bite mark suggests a sixgill shark (*Hexanchus grieus*) may be responsible. The opening left by the sixgill shark allowed several arthropod species to rapidly scavenge the lower torso, reducing the area
to the skeletal state long before the upper torso was scavenged. The scavenging behaviour of immature fish often takes the form of nibbling on exposed fingertips and the facial regions (Boyle et al. 1997; Petrik et al. 2004; Rodriquez, 1997). These postmortem artifacts often appear as small erosions in the flesh (Rodriquez, 1997), and are hard to recognize by an untrained observer (Petrik et al. 2004). Species of whelk and star fish are quick to attach to a submerged body, often consuming the flesh down to bone (Anderson and Hobischak, 2004; Sorg et al. 1997). Turtles create artifacts similar to crabs, which appear as large pits on exposed areas (Rodriquez, 1997).

There have been a few isolated cases in which human limbs were recovered from the stomach of sharks, especially the tiger shark (Boyle et al. 1997; Işcan and McCabe, 1995; Rathbun and Rathbun, 1984). Sharks appear to have a preference for dangling limbs and the buttocks belonging to people swimming in the water. As sharks bite, they roll which causes their teeth to work like a saw (Işcan and McCabe, 1995). This feeding behaviour leaves large gouges on the bone, starting with the initial puncture marks followed by scraping down the bone shaft. While the gouging is significant, there is no evidence of a shark bite crushing or causing visible fractures of the bone (Işcan and McCabe, 1995).

The amount of trauma sustained to the body will affect predation, especially if the surrounding clothing is torn. Soft tissue injuries are the primary spot of consumption for most species because they allow the scavengers easy access to the food source. In the absence of trauma, the next preference for consumption is exposed areas, such as the eyelids, lips, nose, ears, and finger tips (Anderson, 2008; Anderson and Hobischak, 2004; Boyle et al. 1997; Petrik et al. 2004; Sorg et al. 1995, 1997; Teather, 1994).
Blood in the water will provide a scent trail for many species to follow (Gambicourt-personal communication, 2006). Once the carrion is found, the feeding action can be very destructive. The problem for any postmortem examination is that any feeding behaviour, regardless of the species involved, may obliterate any evidence of ante-, peri-, and post-mortem trauma inflicted on the human body (Boyle et al. 1997; Petrik et al. 2004; Sorg et al. 1995, 1997; Teather, 1994). In a sense, scavenging poses a quandary for any forensic anthropological analysis in that colonization by various marine species could be potentially useful in determining time since submersion while their feeding behaviour may mask the initial cause of death.

In the later stages of decomposition a sunken body will meet different ecological functions for different aquatic species. Once the body-as-food stage has past, the bones, either articulated or isolated, provide shelter for aquatic species not interested in feeding on the remains, act as a draw to predators interested in feeding on the shelter-seeking species, and provide a substrate to which barnacles and other grazers can attach to in order to feed on algae and bacteria growing on the bones (Boyle et al. 1997; Merritt and Wallace, 2001; Sorg et al. 1997).

Not only must forensic science examine how various marine species utilize a submerged human body, it must also analyze any environmental condition that prevents scavenging even though scavenging species are in the local area. Barriers can be either natural or man-made and include the type of substrate the body comes in contact with, clothing, and the hull of the vessel. Oxygen and pollution levels of the water need to be examined as well. For example, many species of marine crustaceans often inhabit specific microenvironments and will not predate on submerged carrion outside their home.
domain. Experiments conducted by Hobischak (1998) and Anderson and Hobischak (2004) show that pig carrion suspended in the water column are not predated on to the extent that the sunken pig carrion are for the simple reason that crustaceans may not be able to reach the corpse. It is more apt for the carrion to be scavenged by any terrestrial species having access to the exposed body parts. Once the corpse sinks down to the bottom substrate, marine crustaceans will quickly colonization the carrion, but only if it settle on the appropriate substrate. Unlike crustaceans, fish are capable of feeding on a body not in contact with any substrate (Anderson and Hobischak, 2004).

Tight fitting clothing, like street clothing or a neoprene dive suit, seems to create another temporary barrier to marine scavenging, albeit, only for the first twenty-four hours. Hobischak (1998) noted that the clothing barrier appeared to hinder crayfish scavenging on submerged pig carcasses. Once the pig carcasses breached the water’s surface, clothing presented less of a barrier to several species of terrestrial insect larvae and even acted as shelter for these species.

According to Teather (1994), with the exception of sea lice, most crustaceans prefer to predate on the dermis layers and often do not cross the clothing barrier. The clothing barrier would explain why rescue divers often note seeing evidence of scavenging on the exposed regions of the face and hands, where as the clothed portions appear to be untouched. Sea lice are amphipods which are primarily known for burrowing into a submerged human body through any wound or orifice. Once ensconced in the body, the sea lice will continue to feed until the food supply is gone or they are disturbed during the recovering or autopsy procedures. While it appears that clothing can create a short term barrier to crustacean scavenging, it is not entirely clear if clothing will
continue to do so situations of long term submersion. Many of Teather’s (1994) observations were made during many rescue operations where the duration of submersion was relatively short in time. If the duration of submersion was longer, there may be evidence of crustacean scavenging beyond the dermis layer, especially as the clothing deteriorates. Until research is conducted that address the taphonomy of long term submersion periods, anthropology can not accurately state that clothing will always pose a barrier to scavenging.

Similarly, clothing as long term shelter is only useful as long as the material survives relatively intact. Sorg et al. (1995) examined the partial remains of an adult male contained within an intact military neoprene flight suit. Duration of submersion was estimated to be 32 years. While the bones of the upper body were lost through the neck and wrist openings of the flight suit, the bones of the lower spine, pelvis, both legs, and feet were present. Analysis of the surviving bones showed that the lower spine and pelvis were significantly more eroded than the leg bones. The feet bones showed no evidence of erosion. Sorg et al. (1995) proposed that the bones closer to the suit’s openings at the neck and wrists were more vulnerable to the circulating action of the water and contact with the bottom substrate. The lower portion of the flight suit created a protected microenvironment which prevented the bones of the legs and feet from being damaged or dispersed.

The hull of the vessel poses a third barrier to marine scavenging. The hull of the vessel could pose a barrier to larger predators, as long as the structural integrity is maintained. It is possible that most species of crustaceans will not gain access to the body unless an opening of the wreckage is lying directly on the appropriate substrate. It is
most likely that immature fish and sea lice will have the best chance of accessing the submerged and enclosed body.

In 1997, Campobasso (personal communication, 2006) assisted in the recovery of fifty-three bodies from a shipwreck in the Mediterranean Sea. These bodies had been submerged for seven months before being retrieved. One body lay outside the ship, along the sea floor, and was completely skeletonized, while the human bodies inside the ship were better preserved. This strongly suggests that the local crustaceans could not reach those bodies and thus the enclosed environment preserved the bodies from scavenging.

Other environmental conditions affecting predation are oxygen and pollution levels. According to Merritt and Wallace (2001), low oxygenated or highly polluted environments are not the preferred habitats for most aquatic species. Therefore, biodiversity is low for these environments but the population size for each species tends to be higher as there are fewer competitors to contend with. In contrast, environments with high oxygen and low pollution levels will have a greater biodiversity but population sizes for each species will be smaller. The implication here is that a human body submerged in the low oxygenated environment may not experience significant predation due to a lack of available species. The reduced rate of soft tissue loss associated with feeding will result in a slower rate of decomposition. Human bodies submerged in a highly oxygenated environment containing a higher number of scavenging species will experience accelerated soft tissue loss and enter the advanced stages of decay at a faster rate.

The case studies and experiments presented here provide a valuable insight to human decomposition in aquatic environments. They illustrate that human bodies behave
differently in water than on land, due to water action and differences in the feeding
behaviour of marine species. In an aquatic environment, a human body drifts throughout
the water column and has the potential to travel great distances away from the original
point of entry. Once the body starts to disintegrate, there is a greater potential for
individual body parts to be dispersed over a larger area. It is not as common for human
remains, either as an intact body or as individual body parts, to travel great distances over
land.

When looking at decomposition patterns, it would appear that there is still a
strong reliance on terrestrial insects as indicator species for the determination of time
since submersion in semi-aquatic environments (Anderson, 2008). Fortunately, more
research is being conducted on predation in fully submerged aquatic environments and
forensic science has learned that aquatic species, such as crustacea, will scavenge fully
submerged human bodies, but only if the remains enter into the appropriate
microenvironment where these species have access (Anderson, 2008). Many fish species
will consume human remains floating in the water column, but generally at a rate that is
slower than that which be seen by terrestrial scavenging species.

2.6 Fuel Linkage

One environmental change unique to submersion events, but has been overlooked
in the published literature, is the leakage of fuel into the water. One question this thesis
poses is whether some fuels will retard decomposition by creating a barrier to marine
scavenging while other fuel types accelerate decay by being corrosive to soft tissue. For
example, when the diesel fuel used in many vessels leaks, it permeates through the water
column and coats nearby objects in an oil slick. One only has to think of the massive oil slick produced by the *Exxon Valdez* to understand the environmental devastation that can be caused and the extent to which local marine and terrestrial animals were coated in a thick black layer of oil.

It is common for rescue divers to report poor visibility in capsized vessels due to fuel in the water (Ayres- personal communication, 2008). Under this condition, the recovered human remains are covered in diesel fuel. On sight observations made by Ayres (personal communication, 2008) and Gambicourt (personal communication, 2005) have noted that human remains floating in an oil slick will not be scavenged even through marine predators are in the immediate vicinity. However, human bodies found outside the oil slick will be scavenged. Diesel seems to effect decomposition, but how exactly is still largely unknown. What is the full impact of leaked diesel on the feeding behaviours of scavengers? Do the local scavengers find the coated human bodies unappetizing and ignore the potential food source? Or do the scavengers flee the area to escape the oil, and as such, leave the potential food source behind? Since diesel fuel has been overlooked in the published literature, it is impossible to state which is the case. What can be stated is that the leaked diesel should be considered an important taphonomic agent.

Aviation fuel is a more volatile, hotter burning fuel and will burn skin on contact. Rescue divers often report skin and eye irritation when they try to enter a submerged plane where fuel has leaked into the surrounding water. According to Gambicourt (personal communication 2005), leaked aviation fuel will quickly corrode the dive suits’ valves. Rescue divers are trained to use extreme caution and have limited dive times when entering a submerged aircraft where fuel leakage has occurred. It is possible that in
events of submerged aircrafts, some of the advanced soft tissue loss may, in fact, be due to contact with aviation fuels and not marine scavengers.

Gasoline leaks appear to have the least effect on feeding behaviours than other fuels types (Ayres-personal communication, 2008). It will not coat nearby objects in a layer of oil; nor is it corrosive to soft tissue. Ayres reports seeing local marine scavengers in the vicinity of a ship leaking gasoline but he could not comment as to whether the gas was hindering the feeding behaviour of the scavengers.

None of the literature cited in this thesis has mentioned any type of fuel as a possible taphonomic agent although rescue divers often document it in their reports. It is clear that the documentation provided by the divers needs to be added to the knowledge base utilized by any forensic investigation. Based on what has been briefly discussed in this section, it is not unreasonable to state that leaked fuel is an important consideration for the taphonomic history. Reduced to its most simplistic form, diesel fuel is a deterrent to marine predation where as aviation fuel is an accelerant to soft tissue loss; but until all fuels are fully examined, no definitive conclusion can be drawn at this time.

2.7 Limitations in the Existing Research

Unfortunately there are limitations with the published literature pertaining to decomposition in open aquatic environments. The bulk of the published literature focuses on human remains recovered floating at the water’s surface (Basset and Manhein, 1997, Giertsen and Morild, 1989; Haglund 1993; Simonsen, 1977) or after beaching on the shore (Brooks and Brooks, 1997; Ebbesmeyer and Haglund, 1994, 2002). In many of these cases, the human remains were exposed to both aquatic and terrestrial taphonomic
agents. As a result, the decay rates developed from these publications are based on exposure to terrestrial agents, especially insect activity (Hobischak, 1998; Hobischak and Anderson, 2002; Merritt and Wallace, 2001; Payne and King, 1972).

Terrestrial entomology is vital in determining how long an immersed body has been exposed to air (Goff and Odom, 1987; Payne and King, 1972); but this timeframe may not accurately reflect the length of time the body was completely submerged. Even with forensic science’s diligence in accurately recreating the postmortem history, is the reliance on terrestrial indictors unintentionally skewing the postmortem data for many aquatic environments? Due to this concern, it is vital that forensic science develops decay rates for aquatic environments which are void of any terrestrial agent.

The lack of published literature examining human decomposition in submerged and enclosed saltwater environments makes it difficult to draw analogies. Only two published articles on shipwrecks could be found. One ship wreck occurred off the coast of Hawaii (Kahana et al. 19997) and the other in the Sea of Japan (Lewis et al. 2004). In both cases the authors report seeing differences in the level of decomposition exhibited by the individual human bodies, depending on the specific location inside each ship from which each decedent was recovered. Kahana et al. (1999) and Lewis et al. (2004) determined that inside each ship were smaller microenvironments which contained different taphonomic agents. These differences altered the decay patterns seen in one part of the ship from those seen in another.

Regrettably, no articles documenting human decomposition in submerged and enclosed environments off the coast of British Columbia could be found. This lack of
information suggests there is a gap in the literature examining human decomposition in water, especially for the region of British Columbia.

To address this gap, eighteen submersion incidents involving people trapped inside sunken vessels are examined in this thesis. These incidents are outlined in the following chapter to ascertain whether the decomposition patterning for these human remains support the documented literature on human decomposition in an open aquatic environment.

The multitude of environmental conditions that present when a human body has been submerged, coupled with the condition of the body at the time of submersion, suggests that descriptions for human decay stages and any determination of time since submersion must take into consideration the numerous unique variables presented by submerged environments. Research needs to continue before forensic science can explain the variability of human decomposition in water, particularly when contextualizing the situation for a criminal proceeding.
CHAPTER III

AN EXAMINATION OF CORONER INQUESTS, AUTOPSY REPORTS, AND SAFETY REPORTS

A series of ten marine and air incidents documented by the Coroner’s inquests and autopsy reports from British Columbia and from the safety reports from the Transportation Safety Board of Canada (TSB) in which the bodies of eighteen individuals were recovered from submerged and enclosed aquatic microenvironments are examined here. The primary goal of this research is to examine the stage of decomposition at the time of recovery for each of the human bodies and the taphonomic agents associated with the microenvironment inside each vessel to determine if the presence or exclusion of some taphonomic agents has a retarded or accelerated effect on the decomposition rate. This thesis will specifically look at how the fuel introduced into the aquatic environment affected human tissue loss and impacted marine animal predation.

3.1 Criteria Used in this Thesis

The criteria to be included in this study are as follows: each human body was fully submerged and contained inside the ship, aircraft or automobile from the time of the accident to the time of recovery. This criterion ensures that terrestrial taphonomic agents did not influence the decomposition process. The submersion event had to have occurred in the saltwater off the coast of British Columbia. The submersion period had to be a minimum of 1 hour to ensure the bodies were declared deceased at the scene and no resuscitation procedures were attempted. All age groups are included as are both biological sexes.
3.2 Postmortem Changes Used to Determine the Level of Decompositional Patterning in Each Submersion Event

Synopses events for each submersion incident culled from written reports are used in this thesis. Postmortem pathological findings, including biological profiles, external examinations, clothing descriptors, and the cause and manner of death, were taken from the autopsy reports written by the individual forensic pathologist conducting the autopsy and from the individual coroner overseeing the inquest for each incident. Permission to access these reports was granted by the Chief Coroner’s Office, Burnaby, British Columbia under the Access to Information Act of Canada. Since photocopies could not be made of the autopsy reports, readings were held in the private room of the Chief Coroner’s Office from March 2006 to April 2007.

When available, the climatic and oceanic conditions are also provided in the synopsis and include air temperature, water temperature, local conditions and the body’s recovery location inside the vehicle. This information was taken from the reports written by the Transportation Safety Board’s enquiry into each individual marine and air incident and is based on the information provided by attending rescue divers, police agency, and, at times, the Canadian Coast Guard SAR Unit. The marine and air reports are available from the TSB website (www.tsb.gc.ca) through the Access to Information Act of Canada.

For several of the submersion incidents, telephone conversations were held with the rescue diving units from the Royal Canadian Mounted Police (RCMP) and Canadian Coast Guard (CCG) in order to clarify the information provided in the marine and air reports. More importantly, the divers provided first hand insight vital to understanding the environment in which they entered during the course of the rescue attempts.
For the purpose of this analysis, the stages of decay and criteria for classification are derived from Anderson and Hobischak (2004) as presented in Chapter Two. These stages include submerged fresh, bloat/float, active decay, advanced decay and sunken remains (see Chapter Two, Table 1). The postmortem changes noted on the recovered bodies utilized in this thesis included washer women’s hands, lividity, rigor mortis, bloat, skin marbling, skin discolouration, skin slippages, postmortem artifacts, adipocere formation, disarticulation of individual body parts, dispersal of body parts, and skeletalization. As illustrated in Chapter Two, these decompositional changes are known to occur in an aquatic environment and will be used in the analysis of the collected data in this thesis. For a compilation and definition of known postmortem changes, based on the published literature, see Table 2.
Table 2. A Compilation of Decompositional Characteristics Known to be Present on Submerged Human Remains

<table>
<thead>
<tr>
<th>Decompositional Characteristics</th>
<th>Description of the Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washer Woman’s Hand (Immersion Changes)</td>
<td>Skin starts to pucker on the palmer surfaces of hands and feet.</td>
</tr>
<tr>
<td>Livor Mortis (Lividity)</td>
<td>Pooling of blood into low lying areas of body; either fixed or not fixed.</td>
</tr>
<tr>
<td>Rigor Mortis</td>
<td>Stiffening of joints.</td>
</tr>
<tr>
<td>Bloat</td>
<td>Build up of decompositional gases that cause the body to inflate.</td>
</tr>
<tr>
<td>Skin Marbling</td>
<td>Mottled skin colour.</td>
</tr>
<tr>
<td>Skin Discolouration</td>
<td>Evidence of necrotic tissue. Colours can be blue, green, black etc.</td>
</tr>
<tr>
<td>Skin Slippage (Degloving)</td>
<td>Skin starts to slough off.</td>
</tr>
<tr>
<td>Postmortem Artifacts</td>
<td>Alteration on the body not caused during the perimortem period (e.g. scavenging).</td>
</tr>
<tr>
<td>Adipocere Formation</td>
<td>Presence of a hard waxy substance originating in the subcutaneous fat.</td>
</tr>
<tr>
<td>Soft Tissue Loss</td>
<td>Disintegration of the soft tissue. Soft tissue loss can be accelerated by scavenging or violent contact with environmental debris.</td>
</tr>
<tr>
<td>Disarticulation</td>
<td>Advanced soft tissue loss resulting in the separation of body parts and individual bones.</td>
</tr>
<tr>
<td>Dispersal</td>
<td>The movement of individual body parts way from the rest of the body.</td>
</tr>
<tr>
<td>Skeletal Remains</td>
<td>Little or no soft tissue remains; last stage of decay.</td>
</tr>
</tbody>
</table>
As some of the human remains utilized in this thesis were in a more advanced stage of decomposition than others, each of the above stated postmortem changes are recorded as present or absent for each body. These postmortem changes are used to determine the decompositional stage of each body at the time of autopsy.

Marine and air reports by the TSB provided information on the types of taphonomic agents found inside each wreckage. Data collected include location of recovery inside each vehicle, whether the body was suspended within the water column or had settled on the floor, estimated time since submersion, season of submersion, ambient temperature, the presence of debris and/or fuel in the water, marine animals in association with the human body, and other characteristics of the aquatic environment that were noted during the recovery process. See Table 3 for definitions of each taphonomic agent.
Table 3. Taphonomic Agents Specific to the Microenvironment of Each Wreck

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description of Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of Recovery</td>
<td>Location inside the wreckage where the body was recovered from. Eg. Wheelhouse or bunk.</td>
</tr>
<tr>
<td>Location of Body within the Water Column</td>
<td>Whether the body was suspended within the water column or settled on the bottom.</td>
</tr>
<tr>
<td>Elapsed Time Since Submersion (ETSS)</td>
<td>The duration of time the body was submerged within the wreckage.</td>
</tr>
<tr>
<td>Season of Submersion</td>
<td>The season in which the accident occurred. Recorded as spring, summer, autumn, winter.</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>Water and air temperature- if recorded.</td>
</tr>
<tr>
<td>Presence of Marine Species</td>
<td>The documentation of any marine species in association with the body.</td>
</tr>
<tr>
<td>Presence of Debris/Fuel</td>
<td>The documentation of any floating debris or fuel linkage into the water inside the wreckage.</td>
</tr>
<tr>
<td>Other Characteristics of the Aquatic Environment</td>
<td>Whether the water was clear, murky, calm, or turbulent.</td>
</tr>
</tbody>
</table>

Identifying the types of taphonomic agents present inside each of the wrecks is vital to determining the decompositional pattern as it allows for an analysis of the types of agents working on the submerged human bodies. This taphonomic analysis will demonstrate if the exclusion of some known taphonomic agents from the submerged microenvironment alters the decay pattern from those seen on human remains recovered from an open aquatic environment.
CHAPTER IV
THE ANALYST OF HUMAN BODIES CONTAINED INSIDE SUBMERGED VESSELS

Data uncovered here come from reviewing the marine and aviation events of ten man-made vessels submerged off the coast of British Columbia, Canada over a ten-year period from 1992-2002 and which resulted in a total of eighteen deaths. It is reasonable to state that the ten marine and air incidents outlined in this chapter do not create a sufficient data base from which to make thorough generalizations about decompositional patterning in enclosed submerged environments. The purpose of the information garnered from these incidents is to initiate a beginning dialogue in anthropology into the further examination of the multitude of taphonomic agents commonly associate with aquatic environments.

4.1 Synopsis of Events

Capsizing of the Crown Forest: Decedent 1

On May 15, 1993 the Crown Forest, an 11.28 metre fishing seine, took on water, listed to the starboard side, and capsized while crossing the Skidgate Narrows in the Queen Charlotte Sound. One crew member was able to escape from the wheel house and climb on top of the overturned vessel. He reported that the capsizing occurred at 1715 hours. By 1738 hours, he was rescued by two local fishermen who came upon the scene. There was no sign of the second crew member. A search and rescue attempt ensued. Rescue divers recovered the body of the second crewman from the submerged wheel house at 1838 hours.
Decedent 1 was a 38 year old male, 183cm in length and 91kg in weight. Estimated time since submersion (ETSS) was 1 hour and 23 minutes. At the time of autopsy, foam was present in the airways, livor mortis was general, and rigor mortis was established. No life threatening injuries were noted on the body. Death was consistent with drowning as a consequence of being trapped in a submerged boat. Manner of death was classified as an accident.

Weather data loggers at the Sandspit meteorological recording station, located 15 nautical miles east of the accident, recorded the wind to be blowing from the south-east at 17 knots and the air temperature was 12°C at the time of the accident. The water was at low tide. Weather was not considered a factor in the capsizing.

**Capsizing of the Bona Vista: Decedents 2 and 3**

On July 21, 1993 the Bona Vista, a 12.5 metre pleasure craft, collided with the tug-barge unit of the Artic Taglu/Link 100 off Gossip Shoals at the eastern entrance of Active Pass at 0243 hours. The collision caused the Bona Vista to roll beneath the Artic Taglu and emerge on the starboard side of the tug in a capsized position but still afloat. At 0336 hours a Canadian Coast Guard hovercraft arrived on scene and sent rescue divers into the ship. At 0404 hours, the first victim, a young boy, was recovered from the submerged cabin of the Bona Vista.

Decedent 2 was a male child, 6 years of age, with a length of 105 cm and a weight of 22 kg. The ETSS was 1 hour and 20 minutes. At autopsy, froth was present in the airways, partial rigor mortis was present, and livor mortis was posterior. Associated with lividity was a reddish-blue discolouration which covered the back side of the body. No
life threatening injuries were noted on the body. Cause of death is consistent with drowning as a consequence of submersion in the ocean. Manner of death was classified as an accident.

Within minutes after recovering Decedent 2, the rescue divers recovered the body of an adult male. Decedent 3 was an adult male 35 years of age, with a length of 181 cm and a weight of 87 kg. The ETSS was 1 hour and 20 minutes. At autopsy, froth was present in the airways and water was in the stomach. Livor mortis was posterior and partial rigor mortis was present. A reddish-blue discolouration was noted along the posterior of the body. No life threatening injuries were noted on the body. Cause of death was consistent with drowning as a consequence of submersion in the ocean. Manner of death was classified as an accident.

According to Ayres (personal conversation, 2008), both decedents were covered in a film of oil caused by the fuel leakage. The remaining four of the Bona Vista passengers were found alive in an air pocket, with 10 to 15 cm of diesel fuel floating on top of the water. They died later in hospital due to fuel inhalation and complication due to a near drowning incident. None of the crew members on the Artic Taglu and Link 100 were injured.

At the time of the collision the sea was calm and the visibility was up to 10 km. The tidal flow was in a northerly direction at a speed of less than 1 knot. The prevailing winds were light and from a southwesterly direction.
Sinking of the Marwood: Decedent 4

On August 14, 1994, the Marwood, a 35 metre fishing seine, was berthed alongside the Government Wharf in Ucluelet, on Vancouver Island. Since the crew had gone to shore for the evening, the seine was unattended. As the vessel rose with the incoming tide, the trawl doors caught against the underside of the wharf, causing water to flood the vessel via an open valve in the drain line. The Marwood started to list to the starboard side. At 0245 hours, the chief engineer returned to the vessel and tried to correct the imbalance. He was unsuccessful and the vessel lost reserve buoyancy and quickly sank around 0335 hours.

At 0515 hours, the Search and Rescue Technicians (SAR) from the Canadian Forces Base Esquimalt attempted a rescue but were hindered by oil trapped in the alleyway. In addition, the out-going tide further suspended any rescue attempt as the vessel started to settle along the bottom of the Government Wharf. Rescuers had to wait until high tide resumed before being able to enter the vessel. The chief engineer was found floating at the ceiling in the galley at 1550 hours.

Decedent 4 was a 39 year old male, 179 cm in length and 89 kg in weight. The ETSS was 12 hours and 15 minutes. At autopsy, the decedent was fully clothed, wearing a t-shirt, underwear, shorts, socks, and runners, all of which were stained with oil. Froth was present in the airways, livor mortis was established, and rigor mortis was full. Discolouration was associated with lividity. No life threatening injuries were noted on the body. Death is consistent with drowning as a consequence of being trapped in a submerged vessel. Manner of death was classified as an accident. Tidal conditions were not considered a direct cause of the accident.
Capsizing of the *Courageous*: Decedent 5

On June 20, 1995, the *Courageous*, a 17 metre fishing seine, departed Gig Habour, Washington State en route to Ketchikan, Alaska with a crew of six. The seine entered Johnstone Strait along the Inside Passage of British Columbia where it suddenly heeled to the starboard side and began to list. Once it reached critical list-capability, the *Courageous* capsized around 0339 hours. Five crewmembers abandoned ship and clung to the hull of the capsized vessel which drifted in the water until it grounded off Edith Point. One crewmember asleep in the starboard bottom bunk of the forecastle became trapped below and drowned. Repeated attempts to rescue the trapped crewman by the Canadian Coast Guard failed due to leaked fuel and floating debris creating dangerous diving conditions. Divers eventually recovered the body at 1710 hours.

Decedent 5 was a 21 year old male 186 cm in length and weighed 85 kg. ETSS was 13 hours and 15 minutes. Because the decedent was asleep at the time of the accident, he was only wearing a T-shirt, sweat shirt, denim shorts, and socks. All clothes were still wet at the time of autopsy. At autopsy, froth was present in the airways and immersion changes (washer woman hands) were present on the finger tips. Livor mortis was posterior and rigor mortis was established. Reddish-blue discolouration was present along the posterior side. No life threatening injuries were noted on the body. Cause of death was consistent with saltwater drowning as a consequence of being trapped in a submerged vessel. Manner of death was classified as an accident.

At the time of the accident, the tidal current was ebbing, which caused the flow to move in a northerly and westerly direction in both Seymour Narrows and Johnstone Strait. The ebbing reached its peak at 0320 hours at 2-5 knots near Ripple Point. Wind
was blowing from the opposing direction. It is possible that the combination of these two conditions created the rip tide off Edith Point that may have caused the *Courageous* list and strike the rocky shoreline.

The waters off the north end of Vancouver Island are some of the most dangerous coastal waters anywhere in Canada. The ebb tides and currents flow against the prevailing westerly winds. As a result, rip tides commonly form in that area. These conditions provide a challenge for even the most experienced crew.

**Sinking of the Wolco VI: Decedent 6**

On February 18, 1996, the *Wolco VI*, a 7.8 metre tugboat, was attempting to lift a 10 tonne granite anchor with 70 metres of galvanized steel attached out of the Kwatna Inlet, on the Inside Passage. The excessive weight of the anchor caused the tug’s stern to partially submerge. As the two-man crew struggled with the anchor, the tugboat listed to the port side and rapidly sank. One crewmember jumped overboard and was quickly rescued by people on shore. The second crewmember, still at the wheel, became trapped and went down with the ship.

Professional divers were unable to locate the submerged boat in the hours that followed the accident. On February 24, 1996, a remote operated diving vehicle (ROV) located the boat and decedent in 134 metres of water. Due to the inability of divers to work at such great depths, the tug was towed to shallow water where the body of the decedent was recovered February 28.

At the time of the accident, the decedent was last seen at the wheel of the tug. At time of recovery, the body was located in the rear forecastle area in a port side bunk.
Movement of the body was caused by the pressures associated with rapid decent and deep ocean depths which combined with air pockets to create an extreme pressure that is capable of forcing many objects backwards in the direction of least resistance. Thus, the decedent was forced from the front of the tug to the back where it was pushed through a narrow doorway of the sleeping quarters.

Decedent 6 was a 36 year old male 185 cm in length and 97 kg in weight. ETSS is 240 hours. At the time of the accident, the decedent was in full work clothes, which included boots, work jeans, heavy flannel work shirt, and work coveralls. At autopsy, the body was in the advanced stage of decomposition and immersion changes were evident with extensive postmortem soft tissue loss from the head. Only a small amount of tissue remained around the left and right mastoid processes. The skull, neck, and the upper thoracic area of the vertebral column were completely skeletonized. The eye sockets were empty and the brain was missing. No fractures were noted on the skull which separated from the body at C4, C5 while en route to the morgue. There was complete skeletalization of the left humerus, radius, ulna, and at the left shoulder joint. The distal end of the left clavicle was exposed and skeletonized. The small finger bones of the left hand and wrist were missing. They were recovered the following day at the end of the bunk near to where the left foot would have laid. Fingernails from the left hand were also recovered from the same location. It would appear that the left hand separated from the body and was transferred to the opposite end of the bunk, possibly by scavenging activity. The soft tissue of the right arm down to the mid humerus level was absent. Only the covering skin was present. The fingers of the right hand were partially skeletonized. The first and second ribs were exposed and skeletonized. Most of the internal organs of
the chest and abdomen were missing. Postmortem artifacts caused by marine scavenging were noted on the kidneys. Cause of death was saltwater drowning as a consequence of being trapped in a submerged boat. Manner of death was classified as an accident.

In the morgue, numerous crustaceans were found on the body and in the clothing, but only a few arthropods were collected during the postmortem examination. A forensic entomologist from Simon Fraser University was called in to assist with identifying the species, which were determined to be adult sea lice.

Rescue divers reported the air temperatures to be 4°Celsius and little current in the area at the time of the accident. The accident occurred two hours before high tide which reaches a height of 16.8 feet. Low tide is 4.7 feet and is reached around 0605 hours.

**Capsizing of the Sunboy: Decedents 7 and 8**

On August 7, 1999, the Sunboy, a 13.29 metre pleasure craft, entered English Bay, Vancouver via the Georgia Strait to attend the Symphony of Fire international firework display. At 2145 hours, while traveling towards the firework barge, the Sunboy passed between the tug-barge unit of the Jose Narvaez/Texada B.C. The captain of the Sunboy did not realize that a 274 metre towline connected the tugboat with the coal laden barge. The propellers of the Sunboy became entangled in the towline, which caused the smaller pleasure craft to abruptly stop. Unable to break free, the Sunboy was struck head-on by the on-coming 95.1 metre 5,200 ton Texada B.C. The Sunboy was quickly spun to the starboard side and capsized. Of the fourteen people on board the Sunboy, nine passengers were thrown into the water and rescued.
Five people died, including two women, two men, and a young child. The bodies of the two women were found floating in the water near the scene. The body of one male was never found. The bodies of the second adult male and young child (Decedents 6 and 7) were recovered from the confines of the submerged pleasure craft by Canadian Coast Guard divers around 2300 hours. Both decedents were asleep in the forward cabin at the time of the accident. No one on board the tugboat-barge unit was injured.

Decedent 7 was a 36 year old male, 163 cm in length and 79 kg in weight. His body was recovered from the hull. The ETSS was 1 hour and 15 minutes. At autopsy, froth was noted in the airways, livor mortis was posterior, and rigor mortis was full. Sand was prominent on the face, in the hair, and over the torso region of the decedent. No life threatening injuries were noted on the body. Cause of death was consistent with drowning as a consequence of a boating accident. Manner of death was classified as an accident.

Decedent 8 was a 5 year male child length 124 cm and a weight of 25 kg. The ETSS was 1 hour and 15 minutes. At time of autopsy froth was noted in the airways and a watery fluid was found in the stomach. Livor mortis was posterior and rigor mortis was full. No life threatening injuries were noted on the body. Cause of death was consistent with drowning as a consequence of a boating accident. Manner of death was classified as an accident.

At the time of the accident, the Sunboy was traveling at an estimated speed of 14-15 knots and the tugboat-barge speed was at 7.5 knots. The marine forecast provided by the Weather Centre of Environment Canada predicated that winds were blowing from the southeast at 10 to 20 knots. According to the Transportation Safety Board, on-scene conditions were reported as having overcast skies with good visibility. Water conditions
were choppy and levels were low, with a height of 3.3 metres above chart datum. Tide was ebbing and current speed was traveling in a westerly direction at a rate of less than 1 knot.

**Capsizing of the *Cap Rouge II*: Decedents 9-13**

On August 13, 2002 at 0900 hours the *Cap Rouge II*, a 15 metre fishing seine, capsized in the Georgia Strait shortly after leaving Galliano Island, a small island off the coast of Vancouver. Seven people were on board the vessel at the time of the accident. Two people were able to abandon ship and climb to safety on top of the skiff being towed by the seine. Five persons, including two children, became trapped inside the hull and drowned. The Canadian Coast Guard, the Search and Rescue divers from the 442 Squadron of the Canadian National Defense, and the Royal Canadian Mounted Police dive team, along with numerous nearby boats, made repeated attempts to rescue the people trapped in the seine, often endangering their own lives in the process. Leaked fuel, loose cables, floating mattresses, blankets, and other debris interfered with any attempts at penetrating the ship. All of the decedents were noted to be covered in a film of diesel oil. At the start of the rescue mission, underwater visibility was at 20 feet.

Decedent 9 was an adult male crewmember, 32 years of age with a length of 182 cm and a weight of 90 kg. Rescue divers pulled his body from the wheelhouse around 1000 hours, one hour after submersion. At the scene, his core body temperature was 35°C, indicating the decedent was not hypothermic. At autopsy, froth was present in the airways, rigor was full, and livor mortis was posterior. A reddish-blue discolouration was noted on the body. There was a watery fluid found in the stomach. No life
threatening injuries were noted on the body. Cause of death was consistent with drowning and was classified as an accident.

Decedent 10 was a male child, 9 years of age with a length of 130 cm and a weight of 33kg. His body was recovered from the wheelhouse at 1120 hours by divers. The ETSS was 2 hours and 20 minutes. At autopsy, froth was found in the airways, rigor was full, and livor mortis was posterior. A reddish-blue colour was noted along the posterior side. A watery fluid was also found in the stomach. No life threatening injuries were noted on the body. Cause of death was consistent with drowning as a consequence of a capsized vessel. Manner of death was classified as an accident.

Shortly thereafter, two more bodies were pulled from the flooded main passageway at 1125 hours and 1130 hours respectively. Decedent 11 was a fully clothed adult female, 37 years of age and with a length of 151 cm and a weight of 83 kg. The ETSS was 2 hours and 25 minutes. At autopsy, froth was present in the airways. Rigor mortis was general and lividity was established. Immersion changes (washer women’s hands) were noted on the palm of the hands and soles of the feet. No life threatening injuries were noted on the body. Death was consistent with drowning as a consequence of a capsized vessel. Manner of death was classified as an accident.

Decedent 12 was a fully clothed 40 year old crew man with a length of 170 cm and a weight of 90 kg. The ETSS was 2 hours and 30 minutes. At autopsy, froth was present in the airways and washer women hands/immersion changes were present on the palms of hands and the soles the feet. Rigor mortis was general and livor mortis was established. No life threatening injuries were noted on the body. Cause of death was
consistent with drowning as a consequence of a capsized vessel. Manner of death was classified as an accident.

Deteriorating oceanic conditions, the instability of the ship, the presence of floating debris, and loss of daylight hours made any further attempt at recovering the final victim too dangerous to undertake. At 1555 hours, the decision was made to tow the Cap Rouge II into shallow waters at Deltaport, near Richmond, a suburb of Vancouver. By 1850 hours, underwater visibility was reduced to 2-3 feet. Surviving crewmembers reported last seeing the final decedent in the sleeping quarters. At 1912 hours, rescue divers recovered the final body from said location.

Decedent 13 was a female child, 12 years of age with a length of 139 cm and a weight of 50 kg. Her body was recovered from the forecastle (sleeping quarters) of the vessel 10 hours and 12 minutes following the capsizing. The autopsy revealed that froth was present in the airways, livor mortis was posterior and rigor mortis was full. Immersion changes on the palms and soles were minimal. No life threatening injuries were noted on the body. Cause of death was drowning as a consequence of a capsized vessel. Manner of death was classified as an accident.

At the time of the accident the prevailing current was flowing downstream at the opening of the Fraser River and was flowing at a rate of less than 1 knot. The tide was ebbing at a rate of less than 2 knots. The water off Galliano Island was choppy with waves reaching a height of 1-1.5 metres.
Crash of a de Havilland Twin Otter: Decedents 14-16

On September 17, 1994 a Twin Otter float-equipped plane carrying two pilots and two passengers, departed from a logging camp on Fish Egg Inlet en route to Pruth Bay in the Queen Charlotte Sound. While the plane was gaining altitude, an elevator control cable snapped. The plane stalled 30 metres in the air and plummeted into the water 30 metres from shore at Illahie Inlet. The crash occurred around 1138 hours. The captain sustained serious injuries but was able to exit the plane and swim to shore. The second pilot and two passengers remained trapped inside the submerged plane.

When the float plane failed to arrive at its destination, a rescue mission was undertaken. A search pilot spotted debris in the water around 1430 hours that same day. Floating debris and a fuel spill allowed rescuers to pinpoint the location of the impact. Upon further investigation of the accident scene, the injured pilot was located on shore and taken to hospital. The plane and remaining occupants were recovered after being submerged in the salt water for more than twenty-four hours.

Decedent 14 was a 29 year old male, with a length of 186 cm and a weight of 86 kg. At autopsy, froth was present in the airways, rigor mortis was fully established, and livor mortis was posterior. A discolouration was noticed on the back of the body. No life threatening injuries were noted on the body. It is possible that the impact rendered the decedent unconscious. Cause of death was drowning as a consequence of submersion. Manner of death was classified as an accident.

Decedent 15 was a 33 year old male, with a length of 185 cm and a weight of 72 kg. At autopsy, froth was noted in the airways, rigor mortis was fully established, and livor mortis was posterior. Discolouration mottled the body. Skin slippage was noticed on
the face, neck, right elbow, and right forearm, possibly due to a fuel leak. No life threatening injuries were noted on the body. Cause of death was drowning as a consequence of submersions. Manner of death was classified as an accident.

Decedent 16 was a 64 year old female, with a length of 161 cm and a weight of 75 kg. At autopsy, froth was present in the airways, rigor mortis was established, and livor mortis was posteriorly fixed. Discolouration was noted on the back of the body. No life threatening injuries were noted on the body. Cause of death was drowning as a consequence of submersion. Manner of death was classified as an accident.

**Crash of Flight 709: Decedent 17**

On August 4, 1998 the float equipped de Havilland DHC-Beaver departed Prince Rupert for Kincolith. The float plane carried the pilot and four passengers. Upon arriving in Kincolith, the pilot made three low approaches to the water landing area. On the fourth attempt, around 1758 hours, the nose of the right pontoon dug into the water which forced the plane to flip over. In doing so, the right wing was torn away from the fuselage as the plane crashed into the water. Within minutes, Flight 709 sank. Only the bottoms of the pontoons were visible above the water’s surface. Repeated rescue attempts by eye witnesses were unsuccessful. Only the body of the pilot was recovered from the submerged wreckage by rescue divers at 2138 hours. The bodies of the four passengers were never recovered.

Decedent 17 was a 49 year old male, 188 cm in length and 104 kg in weight. The ETSS was 3 hours and 30 minutes. At autopsy, clothing was noted to be a cotton T-shirt, underwear, socks, and cotton pants. A significant amount of sand was found
encompassing the right sock and shoe. Sand was not found on the left sock or shoe. Froth was found in the airways, rigor mortis was fixed and livor mortis was posterior. Discolouration was noted on the body. Immersion changes to the palms of hands and sole of feet were minimal. No life threatening injuries were noted on the body. Death was consistent with drowning as a consequence of an aviation accident in water. Manner of death was classified as an accident.

Kincolith is located in Nass Bay at the tidal head of three major bodies of water: the Portland Canal, the Observatory Inlet, and the Nass River. During low tide, mud and sand flats are exposed. This condition is known to create turbulent surface conditions. In addition, wind conditions, which are strongly influenced by local mountains and valleys, gust in an excess of 20 knots and blow in from the northwest direction. These gusts often occur in opposition to the direction of the prevailing water current and wave activity, which swell from the southwest.

According to the Transportation Safety Board report, these weather and environmental conditions are considered unpredictable and challenging to maneuver in, even for the most experienced pilots. As a precaution, the landing dock in Kincolith can only be used by floatplanes when water levels are above 3.5 metres. At the time of the accident, the tide was at its lowest point, around 2.7 metres.

**Queen of New Westminster Ferry: Decedent 18**

On August 22, 1992, during the final loading stages of the passenger ferry the Queen of New Westminster, a mini-van with six occupants fell from the upper deck of the loading ramp when the ferry prematurely pulled away from the dock at the Departure
Bay Ferry Terminal in Nanaimo, B.C. The van hit the lower deck of the ferry before flipping over and plunging into the water at 0809 hours. Three of the van passengers escaped from the sinking van and were rescued by BC Ferry employees. At 0828 rescue divers entered the water and retrieved two young girls, both of whom died later in hospital. Further attempts at rescuing the final passenger were delayed due to the severity of the structural damage sustained to the van’s roof, which had to be removed and lifted away by a shore crane. The body was recovered from the back seat of the van by divers at 0930.

Decedent 18 was a 39 year old female, with a length of 174 cm and weight of 95 kg. At autopsy, clothing was noted to be a brassiere, T-shirt, jean shorts, underwear, socks, and shoes. Rigor mortis was general and livor mortis was dependent. Discolouration was noted on the body. A moderate distension was noted in the stomach region. Cause of death was a basal skull fracture and multiple traumas sustained when the van impacted with the loading deck. Manner of death was ruled a homicide. Homicide is a general term used by the British Columbia Coroner’s Service to classified deaths that result from injuries sustained from the direct or indirect action(s) of another person(s) and is not meant to imply guilt or impute blame to that person(s).

4.2 Data

Of all the deaths documented in the synopsis of events, thirteen occurred in ships, four in airplanes, and one in a mini-van. Seventeen of the deaths were ruled to be accidents and one was classified as a homicide. Three of the decedents were adult women and one was a female child. The remaining fourteen decedents were male, with three
being young boys. Ages of the decedents range from 5 to 64 years. Sixteen of the accidents occurred during the summer season, one during the spring, and one during the winter. Not every coroner autopsy or TSB report provided descriptions of clothing for all of the decedents. See Table 4 for the demographic profile provide in the coroner reports. See Table 5 for related details of death and recovery of each individual as gleaned from the coroner and TSB reports.

Table 4. Demographic Profiles of the Decedents – Derived from the Autopsy Reports of the BC Coroner’s Office

<table>
<thead>
<tr>
<th>Decedent Number</th>
<th>Age</th>
<th>Sex</th>
<th>Length (in cm)</th>
<th>Weight (in kg)</th>
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Table 5. Details of Death and Recovery of Each Individual – Derived from the BC Coroners Autopsy Reports and TSB Safety Reports

<table>
<thead>
<tr>
<th>Decedent Number</th>
<th>Manner of Death</th>
<th>Cause of Death</th>
<th>Location of Recovery</th>
<th>Season of Submersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Accident</td>
<td>Drowning</td>
<td>Wheelhouse</td>
<td>Spring</td>
</tr>
<tr>
<td>2</td>
<td>Accident</td>
<td>Drowning</td>
<td>Cabin</td>
<td>Summer</td>
</tr>
<tr>
<td>3</td>
<td>Accident</td>
<td>Drowning</td>
<td>Cabin</td>
<td>Summer</td>
</tr>
<tr>
<td>4</td>
<td>Accident</td>
<td>Drowning</td>
<td>Lower Deck</td>
<td>Summer</td>
</tr>
<tr>
<td>5</td>
<td>Accident</td>
<td>Drowning</td>
<td>Forecastle</td>
<td>Summer</td>
</tr>
<tr>
<td>6</td>
<td>Accident</td>
<td>Drowning</td>
<td>Forecastle</td>
<td>Winter</td>
</tr>
<tr>
<td>7</td>
<td>Accident</td>
<td>Drowning</td>
<td>Hull</td>
<td>Summer</td>
</tr>
<tr>
<td>8</td>
<td>Accident</td>
<td>Drowning</td>
<td>Hull</td>
<td>Summer</td>
</tr>
<tr>
<td>9</td>
<td>Accident</td>
<td>Drowning</td>
<td>Wheelhouse</td>
<td>Summer</td>
</tr>
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<td>Galley</td>
<td>Summer</td>
</tr>
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<td>Summer</td>
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<td>Passageway</td>
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</tr>
<tr>
<td>13</td>
<td>Accident</td>
<td>Drowning</td>
<td>Forecastle</td>
<td>Summer</td>
</tr>
<tr>
<td>14</td>
<td>Accident</td>
<td>Drowning</td>
<td>Cockpit</td>
<td>Summer</td>
</tr>
<tr>
<td>15</td>
<td>Accident</td>
<td>Drowning</td>
<td>Plane seat</td>
<td>Summer</td>
</tr>
<tr>
<td>16</td>
<td>Accident</td>
<td>Drowning</td>
<td>Plane seat</td>
<td>Summer</td>
</tr>
<tr>
<td>17</td>
<td>Accident</td>
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<td>Cockpit</td>
<td>Summer</td>
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<td>18</td>
<td>Homicide</td>
<td>Trauma</td>
<td>Van seat</td>
<td>Summer</td>
</tr>
</tbody>
</table>

The majority of the decedents were recovered during the fresh stage. The submersion period was short for many of the cases due to the work of rescue divers. Decedents 1, 2, 3, 7, 8, 9, 10, 11, 12, 17, and 18 were submerged less than three hours. Decedents 4 and 5 were between twelve and thirteen hours respectively and decedent 13 was nineteen hours. Decedents 14, 15, and 16 were submerged for more than twenty-four hours.
Table 6 Individual Submerge Times for Each Decedent – Derived from the TBS Safety Reports

<table>
<thead>
<tr>
<th>Decedent Number</th>
<th>Submersion Period (in hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.23</td>
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<tr>
<td>2</td>
<td>1.20</td>
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<td>3</td>
<td>1.20</td>
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<td>4</td>
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<td>17</td>
<td>3.3</td>
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<td>18</td>
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</table>

4.3 Results

The most common characteristics were fixed rigor mortis and livor mortis which were noted on all but two of the decedents. These two traits are commonly associated with the early postmortem period. Discolouration was noted on ten of the decedents and its appearance is consistent in the submersion events having two or more decedents. Both decedents 2 and 3 exhibit discolouration and they are from the same marine event. The same is true for 14, 15, and 16, all of which were recovered from the same vessel. Discolouration was not noted in the autopsy reports for decedents 7 and 8, who were recovered together. Yet, for decedents 9, 10, 11, 12, and 13, only decedents 9 and 10 had discolouration where as the others did not. Due to the inconsistent recording of
decompositional traits by the different pathologists, it is unclear if the discolouration was overlooked during the examination or a result of the bodies lying in a supine position in the morgue prior to autopsy.

One phenomenon worth noting is the early appearance of distension/bloating in decedent 18. Bloating is caused by decompositional gas buildup in the stomach and intestines and usually appears around 1-3 days, depending on local environmental conditions. Yet decedent 18 had the early stages of bloating by the time of the accident. The autopsy report offered no explanation for the early onset of this trait. Bloat was not documented in any of the other decedents. See Table 7 for documented decompositional characteristic noted on the decedents at time of autopsy.

Characteristics associated with the later stages of decomposition were more infrequent, mainly due to only one case, decedent 6, having a submersion period long enough to reach the advanced stage. Decompositional patterns with this case are similar to those noted by Hobischak and Anderson (1999) and Kahana et al. (1999) in which sequential stages of decay seem to overlap each other. Decedent 6 was less decomposed in the lower portion of the body while the upper torso region was in the skeletonized stage. This difference can be attributed to significant scavenging of the upper torso by sea lice and clothing protecting the lower body from scavengers.

There is no evidence that adipocere formation was beginning to develop on the body of decedent 6. This is probably due to a combination of several factors. First, significant scavenging by sea lice removed the fatty flesh around the thoracic region. Second, duration of submersion was too short for adipocere formation to begin in the
lower region. Third, evidence of hydrolysis was present but only as at microscopic level and not noticeable by the search and rescue investigators.
Table 7. Documented Decompositional Characteristics Present in Each Decedent at the Time of Autopsy

<table>
<thead>
<tr>
<th>Decedent Number</th>
<th>Washer Women’s Skin</th>
<th>Livor Mortis</th>
<th>Rigor Mortis</th>
<th>Bloat</th>
<th>Discolouration</th>
<th>Skin Slippage</th>
<th>Loss of Body Hair</th>
<th>PM Artifact</th>
<th>Adipocere Formation</th>
<th>Disarticulation</th>
<th>Skeletal Remains</th>
</tr>
</thead>
<tbody>
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</table>

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4.4 Discussion

According to the majority of the autopsy reports, it appears that the decedents originally survived the marine and aviation accidents, only to drown when they were unable to escape their situations. This finding is similar to the conclusion drawn by the Transportation Safety Board’s (1994) survivability study in which the inability for people to escape capsized vessels resulted in drowning. Death was not due to any serious trauma sustain in the event. Similarly, in this thesis, decedents 14, 15, 16, and 17 sustained injuries on impact that were not significant enough to cause death, although they may have hindered the escape process. Instead, death was attributed to drowning as a result of confinement in the submerged planes. Realistically, these findings could also apply to capsized vessels. For decedents 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13, the autopsy reports documented that death was attributed to the inability to escape the lower compartments of the vessel and not to any trauma sustained during the accidents.

Possible scenarios of all of these cases, with the exception of decedent 18, are that the crewmembers and passengers became disoriented and unable to open door latches. It is further possible that the floating debris, which hindered the subsequent rescue attempts, interfered with the decedents’ escape. Floating obstacles, combined with the unstable movement caused by the sinking, may throw escapees off balance, further complicatedly escape.

From this observation, one question that needs to be asked is the effect that rushing water has on the movement of bodies and debris. Does the speed and force of water rushing through windows, doorways, and latches create turbulent waters capable of pushing a body and debris back away from an opening, thus hindering any escape
through doorways or windows? Or is it possible that the confined spaces and passageways of vessels and aircrafts discouraged the current driven movement of debris to other areas? Only the TSB report for decedent 6 commented on the effects of rushing water hindering the escape. Therefore, regrettably, this thesis is unable to answer this question at this time. More research in this area needs to be conducted.

Leaked fuel inside the capsized vessels posed the greatest obstacles for rescue divers to overcome. According the marine and air reports of the TSB and conversation with the RCMP Dive Unit and Canadian Coast Guard SAR Unit, the decedents of the Bona Vista, Marwood, Courageous, and Cap Rouge II, were covered in film of diesel when recovered by rescue divers. Yet, none of the accompanying coroner inquests and autopsy reports make reference to the fuel covering the bodies.

Only one submersion event used in this thesis references the effect of fuel on human soft tissue. According to the autopsy report for event 8, the crash of the de Havilland Twin Otter, the skin slippage reported on decedent 15 may have been the result of leaking fuel and not a decompositional variable. As stated in Chapter Two, aviation fuel is more volatile and burns at a rate hotter than car fuel or diesel which makes it very destructive to flesh.

Fuel in the water may be one reason why marine species were not documented in many of the coroner, autopsy, and TSB reports. Until further research is conducted on the effects of fuel on decomposition, this study is unable to determine the role fuel has as a taphonomic agent. Considering that fuel is capable of burning flesh, it would mix throughout the water column as it rises to the surface and create a barrier in the water column no marine species would want to penetrate. Fortunately, many of the autopsy
reports failed to document whether or not marine scavengers had predated the body. Only the heavily predated body of decedent 6 warranted the consultation of a forensic entomologist.

There are a few possibilities as to why marine scavenging had not been readily documented. First, the action of the submersion event may have disrupted the water to the extent the marine species temporarily fled the immediate area. Second, the bodies did not sustain significant amounts of trauma that would create a scent trail. Hence, there would be nothing in the water to attract the scavengers to the body. Third, the bodies were inaccessible to many marine species due to the structure of the vessel posing as a barrier. Fourth, fuel in the water acted as a deterrent to scavenging. Fifth, the locations of the accidents and the oceanic conditions may not make suitable habitats for many marine species. Therefore, marine scavengers were simply not in the area to begin with. Sixth, any evidence of scavenging left by marine scavengers may have been overlooked or considered inconsequential to the investigation.

Due to the short duration of submersion for many of the decedents, it cannot be determined to what extend, if any, oceanic and weather conditions had an effect on rates of decay. Only decedent 6 was submerged long enough to be in an advanced stage of decay in which disarticulation occurred with the left hand. Movement of the left hand was attributed to scavenging and not current flow.

Unless there is a flushing action occurring inside the wreck, usually caused by water flowing in and out of two separate openings, current flow rarely occurs inside any wreckage. Therefore, it is reasonable to suggest that the wreckage protected decedent 6
from current activity. Also, considering that the wreck was recovered from 134 metres of water, it is unlikely that tidal fluctuations were able to act upon the body at that depth.

Similar to the problems experienced by Hobischak and Anderson (1999) and Petrik et al, (2004), the generalized documentation provided in the coroner inquests and autopsy reports limited the ability to recreate the postmortem history of each decedent in great detail. Information pertaining to the postmortem external examination was limited and vague. Other important information, such as the ambient temperatures inside the submerged wreckage, depth of the wreckage, the presence of marine species, and the position of the body in the context of the scene, were never recorded. In agreement with these authors, more training and education for forensic investigators is necessary to improve our understanding of the postmortem history of bodies recovered from any aqueous environment. Hobischak and Anderson’s (1999) suggestion for the development of a checklist to be used by investigators at the scene would greatly improve detailed and consistent documentation and would aid future research.

A more systematic documentation would prevent the loss of valuable information, as appears to be the case with leaked fuel. Phone conversations held with Doug Gambicourt of the RCMP Dive Unit (2005) and Bob Ayres of the CCG SAR Unit (2008), illustrated how observable information such as fuel barriers and changes in predation behaviours are noted at the scene but rarely make it into any autopsy report. Therefore, it is difficult to assess whether the lack of predation for many of the submersion events used in this thesis is due to the leaked fuel or other factors. This lack of detailed documentation in the autopsy reports greatly limited the depth to which this thesis could examine the taphonomic agents contained within submerged and confined vessels. It
would be highly beneficial if the on scene observations made by the rescue divers were documented in the reports as it would provide a more thorough understanding of the taphonomic history of the human remains.

One final consideration this study would like to present is the effects of transport on the human body. The goal of this study was to provide a description of various types of decay patterns associated with fully submerged and enclosed compartments; but the information gathered was documented at the time of autopsy. The act of transporting the body from the site of recovery to the morgue creates a second environment to which the body is exposed. The morgue provides a third. It should be noted that prior to autopsy, all decedents used in this study were placed in morgue refrigeration units, with the autopsies being conducted within 24 hours following the recovery. According to Strathoff (personal communication, 2007) common practice is to keep the refrigeration units between 2°-6° Celsius, which slows the decay rate significantly.

As stated in the introduction of this study, decomposition occurs more rapidly in air than in water, thus movement from water to land could potentially accelerate decomposition due to exposure to warmer air temperatures and other terrestrial factors. From this information, one consideration that was investigated was the effect the recovery process could have on decomposition rates. When a body is extracted from water, is there a chance that exposure to warmer air temperatures could accelerate the decomposition process? Most likely the answer to this question is no. A body submerged in cold water will maintain its thermal mass for several hours following extraction as long as it is not exposed to any heat source or sarcosaprophagus insects. Thus, the effects of
transporting the body should be minimal as along as transportation to the morgue is within several hours (Strathoff-personal communication, 2006).

In saying that, it is still pertinent that experiments are conducted to ensure the recovery process is not effecting decomposition rates. Fully submerging pig models in enclosed compartments and leaving them for an extended period of time is the only way to monitor long term postmortem changes and determine the effects recovery has on the decay process.
CHAPTER V
CONCLUSION

The purpose of this thesis was to collect and supply observable baseline data on the decompositional patterns pursuant to the saltwater microenvironment of the British Columbian coastline. From this study, a limited understanding of the decay process in enclosed submerged environments was provided which will eventually permit forensic anthropology and other fields in forensic science to develop normative standards for the assessment of time since death/submersion. Since this study provides a brief window into the postmortem changes occurring in the first twenty-four hours following submersion in an enclosed compartment, it is particularly important that research continues in this area. Such data will be useful for a variety of purposes, both theoretical and practical. First, it will provide norms for decomposition in fully submerged enclosed compartments for the saltwater environments off the coast of British Columbia, Canada. Second, it creates comparative studies of decomposition with other aqueous environments. Third, it contributes to the prediction of time since death/submersion when time of death is unknown.

Even though the published literature has addressed some of these issues, important gaps exist in the research, mainly leaked fuel as a taphonomic agent and the potential effect of transporting the human remains from the scene to the morgue. Current research being conducted by Gail Anderson (2008) off the coast of British Columbia examines scavenging behaviours on pig caresses submerged for extended periods of time.
Anderson’s research is suggesting that predation behaviours noted during the early submersion period differ from those noted in more advanced decomposition stages.

The main barrier to overcoming the limitations seen in this study lies in improved documentation and an understanding of the unique scenarios presented by aqueous environments. While similarities exist between macroenvironments, each microenvironment will still present its own set of unique challenges and insights into the understanding of human decomposition by addressing the difficulty in differentiating between what is typical and what is unique to any submersion situation.

At this time, this newest area of forensic research is far from being able to develop accurate time since submersion timelines for bodies recovered from submerged compartments. However, with the progress being made by the continuing research into the areas of decomposition in aqueous environments, future decomposition studies can hope for more consistent and detailed documentation of the decomposition characteristics present on the body at scene and in the morgue. It is the hope of this thesis that the discussion provided will encourage the forensic community to take on the challenges of the aquatic world and expand its knowledge of the multitude of factors influencing the postmortem history of human remains.
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