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The Applicability of the Postmortem Submersion Interval Estimation Formula for Human Remains Found in Subtropical Aquatic Environments

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The Applicability of the Postmortem Submersion Interval Estimation Formula for Human Remains Found in Subtropical Aquatic Environments

by

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Abstract

Within the past decade, several attempts have been made to standardize a method for estimating postmortem submersion intervals (PMSI); however, the majority of these studies have focused on data from a temperate climate which cannot be taken as representative of large portions of the globe. Thus, there are large portions of the earth in which the methodology from these studies may not be able to accurately estimate PMSI which has the potential to leave investigators in these other climatic zones at a disadvantage. This presentation presents a case study into the applicability of two Total Body Scoring Systems (TADS) utilized for estimating PMSI by Heaton et al. (2010) and van Daalen et al. (2017) for remains found within aquatic environments in subtropical climates. To this aim, data was collected from temporal photographs of cadavers donated to the Institute for Forensic Anthropology and Applied Sciences (IFAAS) that were taken while the donors were placed at the USF Facility for Outdoor Research and Training (USF-FORT) located in Tampa, Florida. The nine donors eligible for this study had been placed in a naturally occurring, freshwater, ephemeral, aquatic environment and allowed to decompose with limited intervention throughout a period of time between July 7th, 2019 to March 15th, 2021 (between 31 to 600 days). From this period of time, a random date, for which photographs were available, was chosen, that fell within a period in which the remains were in a state of active decomposition (between 4 and 31 days), to serve as the date on which the donor would be scored with the TADS systems and would provide a known PMSI with which the estimated PMSI could be compared. The results of this analysis indicate that the Heaton et al.

TADS system has a lower degree of interobserver error than the van Daalen et al. system and can estimate PSMI with a high degree of accuracy for remains who are given a TADS score under 20.

Introduction

Since the late 1970s, forensic anthropologists have become increasingly interested in the processes surrounding the decomposition of human remains and how it can be used by forensic investigators within criminal investigations. Overall, research on human decomposition has been instrumental in increasing the accuracy of postmortem interval (PMI) estimation which is integral to the investigations performed by law enforcement to whom possessing a reliable estimation of when a person died can be crucial for furthering the investigation. However, the majority of research produced since then has focused on decomposition in terrestrial environments, leaving areas with higher rates of aquatic decomposition lacking in potentially crucial resources.

According to the National Oceanic and Atmospheric Administration, Florida possesses a shoreline mileage of 8,436, a measurement that includes, "offshore islands, sounds, bays, rivers, and creeks to the head of tidewater or to a point where tidal waters narrow to a width of 100 feet" (NOAA Office for Coastal Management). Additionally, 18.5% of Florida is covered in water, equaling roughly 65,758 total square miles (Water Science School 2018). For a state with so much water, it can be expected that a fair number of deceased individuals are found within aquatic environments, though there are no official reports on this matter. However, not all aquatic ecosystems within the state exist throughout the entire year. These environments are often referred to as ephemeral wetlands, ephemeral pools, isolated wetlands, Carolina bays, seasonal ponds, cypress domes, sinkhole wetlands, seasonal marshes, intermittent ponds, pineland depressions, depressional wetlands, or vernal pools (Means and Johnson 2008). Ephemeral wetlands can be found throughout Florida, typically during the spring and summer months, and are characterized as generally isolated areas of water that go through cyclical periods of drying and refilling called a hydroperiod (Means and Johnson 2008). These wetlands can last from anywhere between 1-2 weeks to 1-2 years, though this period of time can vary from year-to-year depending on environmental factors. Ephemeral wetlands are home to distinctive ecosystems whose flora and fauna are uniquely suited for this environment. The majority of these organisms spend the dryer months as drought-resistant seeds, eggs, or cysts that will grow and reproduce during the wet months. These wetlands also attract various birds, reptiles, and mammals that utilize the abundance of new life as a food source (National Resources Conservation Service 2007, 3).

Given Florida's abundance of potential sites of aquatic decomposition, the current lack in literature surrounding the specifics of these processes within the state leaves investigative agencies and consultants without potentially integral resources from which to draw. While aquatic and terrestrial decomposition do share many similarities, the research done on one cannot simply be applied to the other. As shall be touched on briefly in the following section, individuals who are exposed to an aquatic environment while decomposing are subject to several phenomena that do not affect individual decomposing in terrestrial environments. While these phenomena do not negate or necessarily change the typical order in which decomposition takes place, they can impact the overall decomposition timeline; namely speeding or slowing the process depending on the specific scenario. Due to these differences, the exact formulas used for terrestrial remains cannot be expected to work with non-terrestrial remains, thus necessitating a separate but related system for aquatic decomposition. Additionally, as temperature is a known factor that can greatly impact decomposition, it can be further said that methods of estimating time since death for aquatic remains that were created using data from one location may not be viable for use in other locations. Therefore, even the limited literature that does currently exist on the estimation of PMI for individuals found decomposing in waterlogged environments cannot necessarily be applied to remains found in Florida without being tested first as there is no guarantee that a method created and validated within a different climate will work for subtropical Florida. The current study aims to lessen the current knowledge gap of potential methods for the estimation of time since death for individuals found decomposing in aquatic ecosystems through the investigation of decomposition in ephemeral aquatic environments in a subtropic environment and how the taphonomic changes associated with decay in these locations can be utilized to estimate information regarding the length of time the remains have been decomposing. Specifically, this study examines two methods for estimating the time since death of aquatic remains that were published within the past decade to see whether they are applicable for use in a subtropic environment despite their being created using decomposition data from two separate temperate climates.

Literature Review

An Introduction to Postmortem Interval Estimation

As stated by Sutton and Bryd, the estimation of PMI, “plays a role in implicating or excluding suspects, corroborating or refuting suspect alibis, and uncovering the specific circumstances and chain of events that led to the death of the individual in question” (Sutton and Byrd 2020, 3). While decomposition studies have led to other important insights, such as the damage that can be inflicted on bones by scavengers or how remains may be expected to be scattered in cases where the body is left to decompose out in the open, the vast majority of decomposition based studies are undertaken with the intent of adding to the literature regarding the many factors that can impact how the human body decomposes and how those factors can in turn affect the estimation of PMI.

One of the most influential studies within this vein of research was entitled *Using accumulated degree-days to estimate the post mortem interval from decomposed human remains* by Megyesi et al.. This study explored a method for estimating PMI based on scoring decomposing remains using a point-based total body scoring system while taking into account temperatures affecting the remains through the use of accumulated degree days (ADD) (Megyesi et al. 2005). Since its publication in 2005, this article and the methods within it have been cited hundreds of times and continue to be the basis on which many estimate PMI today.

While the decomposition of humans has technically been studied for thousands of years, with one of the earliest studies coming from 13th century China (Sutton and Byrd 2020, 1), the majority of decomposition based studies revolve around how a body decomposes within a terrestrial environment. Considering over seventy percent of the earth is covered in water, the overall lack of emphasis on the decomposition of humans in aquatic environments leaves forensic researchers and investigators with large gaps in their knowledge pool. Within those studies that have focused specifically on aquatic decomposition the main focuses have been on: the initial, fresh, stages of aquatic decomposition, the improvement of the methodology that surrounds the estimation of time since death specifically for individuals found within bodies of water, and other factors that may or may not impact the rate of decomposition in aquatic ecosystems.

Aquatic Death and Postmortem Submersion Interval Estimation

There are many different reasons why the remains of a deceased individual may end up in a body of water whether they died in said body of water or were deposited there after death. When a body is found in the relatively early or fresh stages of decomposition, to the point where an autopsy can still be performed, medicolegal death investigators can look at the autopsy findings to estimate not only PMI, or postmortem submersion interval for aquatic cases, but also to establish a cause and manner of death (Armstrong and Erskine 2018)(Lunetta et al. 2014, 1179-1180). Postmortem submersion interval (PMSI) refers to the time since the remains entered the water to the time they were recovered from said water. In many cases the cause of death for individuals found in water is drowning, however even in cases where this is true the manner of death is still questionable. After all, the drowning could have been an accident, suicide, homicide, or undetermined (Lunetta et al. 2014, 1186-1187). However, once decomposition begins to progress, the accuracy of autopsy findings diminishes until the point where an autopsy is impossible and investigators must rely on visual aquatic decomposition cues to estimate PMSI. The earliest of these visual cues is a white or pink foam that is present around the nose and mouth of the individual that will return even after being removed (Armstrong and Erskine 2018). Other signs of aquatic decomposition include: the wrinkling and sloughing of the skin of the hands and feet referred to as "washerwoman's hands", cutis anserina or gooseflesh, and the formation of adipocere through the process of saponification (Armstrong and Erskine 2018)(Caruso 2016). In addition to these aquatic specific decompositional changes, the remains also go through similar stages to those that are on land such as: skin discoloration, marbling, purging of fluids, bloating, and overall breakdown of the soft tissue (Armstrong and Erskine 2018).

PMSI Estimation Based on Non-Human Actors

While human remains do go through similar stages of decomposition in terrestrial and aquatic environments, with a few aforementioned additions, the rates at which they go through these stages varies widely, which has made the investigation of specific occurrences related to aquatic decomposition necessary for the improvement of PMSI estimation. Several different methods have been proposed for use with PMSI estimation with varying degrees of usability and accuracy. Multiple studies have specifically investigated the potential for using aquatic insects for PMSI estimation, much in the same way that terrestrial insects, specifically Calliphoridae or blowflies, are used in PMI estimation. Wallace et al. examined the growth phases of the aquatic caddisfly larvae for this specific purpose. The study found that the analysis of growth phases of those aquatic insects that are attracted to decomposing remains can be useful for the overall estimation of PMSI, though it may be best suited for narrowing the estimation period (Wallace et al. 2008). Similarly, Dalal et al. examined the stages at which different insects, both aquatic and terrestrial, though with greater focus on the aquatic, are observed on remains that are left to decompose in bodies of water found within the hot and arid climate of Haryana, India. The researchers identified 2385 insects that were associated with the five identified stages of decomposition within this study throughout multiple seasons. In addition to the identification of these insects, the study found that a further examination of the life cycle of chironomids in particular has the potential to be incredibly important to the estimation of PMSI (Dalal et al. 2020).

Other studies have focused on examining the microbiomes found on decomposing remains for use in PMSI estimation. Cartozzo et al. found that by analyzing the bacteria found on submerged skeletal elements from pigs, ribs and scapulae, they could estimate PMSI within approximately 27–29 days over a duration of one year's submersion (Cartozzo et al. 2021). However, as this study was conducted using already skeletonized remains, the findings would need to be validated with testing on fresh remains throughout the decomposition process. Another study, out of the Republic of Korea, by Hyun et al. took a similar approach to PMSI estimation by using next-generation sequencing (NGS) to identify the micro-eukaryotic communities that were attracted to pig remains. Hyun et al., unlike Cartozzo et al., used the remains of freshly deceased pigs for their study, as well as the hood from a car as an abiotic control. The study found that the richness of taxa may not be a good estimate of PMSI, however the relative abundance pattern of certain microeukaryotes, such as certain forms of algae, might be a good indicator to infer PMSI (Hyun et al. 2019). Like Cartozzo et al., the results of this study would need to be further investigated and replicated to validate the usefulness of NGS and micro-eukaryotic communities for PMSI estimation.

While the majority of non-human based PMSI estimation methods focus on the use of insect life cycles or bacteria communities, other potential methods for estimating PMSI have been published within the past several years. Magnia et al. examined the potential usefulness of barnacle colonization rates on various fabrics for the purpose of PMSI estimation. The study focused on four different types of fabric that are commonly used in clothing and wetsuits: neoprene, satin, cotton, and velvet. It was found that water temperature and type of fabric do have a direct effect on the number of colonizing barnacles; and that in the event of a forensic case where barnacles are found on clothing, the specimens that will provide the most information will be the ones colonizing the exposed side of thick synthetic fabrics such as neoprene, while barnacles colonizing natural fibers, hair-like surfaces, creases and folds should be avoided (Magnia et al. 2021). Alternatively, a study by Macfarlane et al. looked at the possibility of using measures of water quality to narrow PMSI estimation. This study measures the pH, dissolved oxygen, turbidity, conductivity, total organic carbon (TOC), nitrite, nitrate, and heterotrophic bacteria of water from a tank containing the remains of mice. It was found that peak changes in conductivity, turbidity, and TOC parameters aligned with indicators of a partially decomposed carcass. The study concluded that results preliminarily suggest that water quality parameters, such as conductivity, turbidity, and TOC, could serve as potential indicators in estimating PMSI in surface water bodies (Macfarlane et al. 2020). However, the results of this study would need to be validated by further testing.

PMSI Estimation Based on Decomposing Human Remains

Since human remains do go through similar but still noticeably different stages of decomposition in terrestrial and aquatic environments the creation of PMSI specific equations is necessary for the analysis of remains found in aquatic environments. One such equation was developed by Heaton et al. from cases of remains found within the waterways of the United Kingdom. Heaton et al. based the structure of their PMSI equation on the work done by Megyesi et al. whose PMI estimation method used ADD and a total body scoring system in which each stage of decomposition is associated with a progressively increasing numerical score that can be assigned to each major area of the body: face, trunk, and limbs, which are then added together for a single total decomposition score (Heaton et al. 2010, 302-303). Heaton et al. applied the use of ADD and a total body score, which they termed a total aquatic decomposition score (TADS) (Heaton et al. 2010, 303-304). The equation that was produced through this study was able to accurately estimate PMSI from visual observations of decomposition, however, given that the samples used to verify the accuracy of this equation were only taken from the United Kingdom, Heaton et al. were cautious in pronouncing the accuracy of their methods for other climatic regions (Heaton et al. 2010, 307).

This concern was proven to be warranted by Humphreys et al. in a study they did testing the validity of the Heaton et al. PMSI estimation method versus the overall less accurate method of mass reduction in a California reservoir (Humphreys et al 2013, 513-514). When using the exact equations for ADD and TADS put forth by Heaton et al., Humphreys et al. found that the ADD was underestimated and the TADS was overestimated which led to an inaccurate PMSI estimation (Humphreys et al 2013, 516-517). Once Humphreys et al. accounted for the differences in climate between California and the United Kingdom and adjusted the equation accordingly, though, they were able to estimate PMSI with a higher degree of accuracy. Another method for PMSI estimation was later developed by van Daalen et al. in which they only used the TAD scores that they had created instead of additionally using ADD (van Daalen et al. 2017).

While this method held a high degree of accuracy for their study area of the North Sea, like Heaton et al. there was a high probability that the method would not work in other climates unless modified in some manner (van Daalen et al. 2017, 371-372). The methods of Heaton et al. and van Daalen et al. were tested against each other by Palazzo et al. (2020 and 2021) in both freshwater and marine environments within a Mediterranean climate. The first Palazzo et al. study on using these TAD scoring methods in freshwater found that accurately estimating ADD and PMSI using these two methods can only be done if the data is split between two seasons, cold and warm (Palazzo et al. 2020, 2-5). However, the later Palazzo et al. study on the same methods applied to marine environments found that this seasonal split was not necessary for remains found within bodies of saltwater, though ultimately still preferable (Palazzo et al. 2021, 6-7).

Human Decomposition in Aquatic Contexts and Factors that Impact this Process

The work of the Palazzo et al. studies highlight the importance of multiple factors in the decomposition process. The greatest of these factors is generally temperature, though even the effects of temperature can be lessened by factors such as salinity (Palazzo et al. 2021, 6). There are of course other factors whose influence on decomposition have been studied to various extents in the past fifteen years.

Faunal Influences

One such factor that can greatly impact the rate of decomposition if present is the scavenging of the remains by aquatic animals. Anderson and Bell performed two studies that examined the impact of scavenger activity on pigs as human analogues and found that while scavenger activity is not the same throughout the entire year, heavy scavenger activity can cause complete skeletonization of remains before there are any signs of decomposition (Anderson and Bell 2014)(Anderson and Bell 2017). This would make estimation of PMSI nearly impossible for the majority of the methods discussed above and can cause significant issues for forensic investigations.

Water Influences

Other potential influential factors include laminar flow and water pH which can both affect the rate at which soft tissue degrades. A study by Christensen and Myers tested the effects of water pH on the degradation of bovine bones within a controlled environment. They found that while bones that were left in extreme pH's either completely dissolved (pH 1) or degraded until unrecognizable (pH 14), all pH's between these two extremes had little effect on the bone itself. Though depending on the pH, flesh was preserved or degraded to various extents. Since the pH range for bodies of water in the United States generally stays within a pH range of 4.3-10 it was concluded that water pH within these bodies of water would be unlikely to have a significant effect on the preservation or degradation of bone and surrounding flesh (Christensen and Myers 2011). Another recent study by Christy Palmer examined the impact that laminar flow can have on the decomposition process and the accuracy of PMSI estimation in flow versus non-flow environments. Palmer, using rabbit carcasses that were submerged in either a flowing river or a non-flowing canal, found that flow had a significant impact on decomposition and that PMSI estimation methods that did not factor in the effects of laminar flow did not produce accurate results in non-flow environments if their methods were originally based on results from flow waterways (Palmer 2020).

Body Influences: Body Mass and Adipocere Formation

Whether the living body mass of an individual impacts how they decompose after death has received conflicting levels of support throughout the larger forensic community. For instance, Sutherland et al., using pigs as human analogues, found that rapid decomposition occurs during the primary stages of decomposition for both pigs with large body masses and pigs with small body masses. However, large pigs showed a plateau phase during the advanced stages of decomposition in which decomposition was minimal. The largest of the smaller pigs went through a similar plateau though it was much shorter in length than their larger counterparts. The smallest pigs did not go through a plateau phase and they decomposed quickly. Sutherland et al. concluded that body mass does have an effect on the rate at which individuals will decompose as overall the small pigs decomposed 2.82 times faster than large pigs (Sutherland et al. 2013). Conversely, Roberts et al. found through their 2017 study on the effects of body mass on adult decomposition in a terrestrial environment that body mass likely has a minimal impact on postmortem interval estimation even when seasonal differences were taken into account. However, the study also found that those cadavers with larger body mass did possess increased adipose tissue liquefaction, greater adipocere formation, and displayed a relatively larger cadaver decomposition island which could suggest potential impacts for aquatic environments (Roberts et al. 2017).

The formation of adipocere can complicate the PMSI estimation process as it essentially causes the stages of decomposition to come to a halt for hundreds, or in some cases thousands, of years. Adipocere forms on decomposing remains through the process of saponification in which the decomposition of adipose tissue facilitated by intrinsic lipases as well as the enzymatic activity of micro-organisms that originate within the intestines and respiratory system (Magni et al. 2021, 2). There are many different factors that can impact whether or not adipocere will actually form on decaying remains as discussed by Magni et al., however, locations with mildly alkaline pH, moisture, anaerobic conditions, warm temperatures and presence of bacteria are considered to be ideal for its formation (Magni et al. 2021, 5). While human remains found in water may not form adipocere even when in what appears to be the proper conditions, the formation of adipocere is considered the end of decomposition as it essentially preserves the body (O'Brien and Kuehner 2007, 298-300). This was further highlighted by Widya et al. in which rabbit carcasses were split into two groups, a control group in which the rabbits were left to decompose on the open ground and an experimental group in which the rabbits were submerged in buckets of water. By the end of the study experiment, no adipocere had formed on the rabbits in the control group whereas the rabbits in the experimental group did show early stage adipocere formation. The results of the study led Widya et al. to conclude that the greater the ADD, the more likely adipocere is to form on the remains (Widya et al. 2012). However, they also acknowledge that this study would need to be replicated using human cadavers or more suitable human analogues in different environments to validate these findings.

Methods

This study was conducted in several steps, beginning with the collection of relevant data from the University of South Florida's Institute for Anthropology and Applied Sciences' (IFAAS) donor database. From this database information was collected concerning nine donors who had been placed within the confines of the USF Facility for Outdoor Research and Training (USF-FORT) in a naturally occurring, freshwater, ephemeral, aquatic environment and allowed to decompose with limited intervention throughout a period of time between July 7th, 2019 to March 15th, 2021 (between 31 to 600 days). Within this study, a natural body of water is defined as a permanent or semi-permanent water feature of a significant size, i.e., not bathtubs, and that have not been treated with purifying chemicals such as those used in swimming pools or hot tubs. For each donor, the following information was collected: donor designation number, date the donor was placed out at USF-FORT, the date they were retrieved from USF-FORT, the average outside temperature per day, as well as all available photographs that were taken of the remains while they were left to decompose. During the period of time when data was being collected on the decomposition of these donors, USF-FORT was located in Pasco County, Florida (28°18'29.5"N 82°29'25.2"W), thus, publicly available past temperature records from Pasco County were used to gather the average outside temperatures needed for this study. These past temperatures were originally recorded in Fahrenheit and were collected as such.

Once this information was collected, a semi-randomized date was determined for each of the donors based on the photographs available for said date. This meant that the date had to be selected from the period in which the remains were still actively decomposing (between 4 and 31

Table 1 – Definitions *for TADS, FADS, BADS, and LADS*

Total Body Aquatic Decomposition Score Systems (TADS)	A summation of progressive numerical scores based on three areas of the body: the head, the trunk, and the limbs
Facial Aquatic Decomposition Score (FADS)	A numerical score assigned to the head region of a set of remains
Body Aquatic Decomposition Score (BADS)	A numerical score assigned to the trunk region of a set of remains
Limbs Aquatic Decomposition Score (LADS)	A numerical score assigned to the limbs of a set of remains, all limbs are viewed together for a singular score

days), and that the photographs available showed the head, trunk, and limbs of the individual to some extent so that scoring could be conducted. From those dates that met this criterion a randomized date was selected for each donor. These days would be considered the *known PMSI* of each donor. Each of the nine donors were then scored for that selected date according to the Total Body Aquatic Decomposition Scoring systems as outlined in Heaton et al. and van Daalen et al. (See Appendix I for these systems).

Both Heaton et al. and van Daalen et al.'s TADS scoring systems are based on the PMI TADS system developed by Megyesi et al. as mentioned previously. Heaton et al.'s system is made up of a FADS and BADS where potential scores range from 0-8 and a LADS score that ranges from10-9 where 1 indicates that no signs of decomposition are present and 8/9 that indicates that decomposition has ended either by complete skeletonization or adipocere formation. van Daalen et al.'s system is made up of a FADS, BADS, LADS where potential scores range from 1-6 with 1 indicating no visible signs of decomposition and 6 indicating complete skeletonization. For this system each score is then broken up into sub scores (ie. 2.1, 2.2, 2.3, etc.) that goes into the common attributes of certain stages (See Appendix I). While the two systems differ in terms of format, both are based on generalized observable phenomena that are known to characterize how a decedent is expected to decompose (autolysis, bloat, active decay, and skeletonization) in a generic aquatic environment. Since these systems utilize visual changes to mark stages of decomposition, any remains that can be seen, whether in person or through photographs or video, can be scored. Additionally, because they are relatively generic and simplified they allow for greater ease of use among observers as long as said observers are familiar with the signs and stages of decomposition. This can however be an issue for observers who are not as familiar with decomposition and can thus lead to errors in scoring, and estimation. The generalized nature of these systems can also lead to errors in cases where decomposition does not follow the expected stages, whether due to human intervention such as placing the remains in sealed garbage bags or environmental factors such as extensive scavenging. Remains whose decomposition patterns have been altered in such a manner would not be able to be scored with reliability for estimation purposes.

While van Daalen et al. did not use temperature data or ADD in their original methodology, the current study employes the use of ADD in the analysis of both systems in accordance with the research of Palazzo et al. (2020 and 2021). These studies found that the use of ADD with both the Heaton et al. and the van Daalen et al. methods greatly increased the relationship between PMSI and the TADS scores.

Initial statistical analysis was conducted to test the interobserver agreement of these scoring methods. To this aim, four individuals who all have at least three years of experience actively working with decomposing human remains, in addition to the author, were asked to score the nine donors for their selected known PMSI date, utilizing the images available and the two separate scoring methods. While none of the individuals have performed research concerning aquatic decomposition, each was familiar with the observation of decomposition in aquatic environments due to their work and affiliation with USF-FORT. These data were then taken, along with the author's initial scores, and inputted into the statistical processing software SPSS to test for the level of agreement between scorers. Fleiss' kappa was used to analyze the rate of interobserver agreement because of its ability to assess the level of agreement between two or more observers (Fleiss 1971) (Fleiss et al. 2003)

In addition to the total body scores, ADD was calculated for the *known PMSI* of each donor.

$$\text{ADD} = \sum \text{Average daily temperature for the entire PMSI}$$

In accordance with the methods of Heaton et al. and Palazzo et al. 2020 and 2021, ADD was log transformed so as to fill the requirements of a normal distribution using SPSS. Multiple linear regression analysis was then performed to test the significance of Heaton et al. TADS, FADS, BADS, and LADS in relation PMSI and logADD and van Daalen et al. TADS, FADS, BADS, and LADS in relation to PMSI and logADD. Multiple linear regression was chosen for this analysis because it allows for the exploration of possible relationships between more than one independent variable and a corresponding dependent variable. In the case of this study, known PMSI and logADD are the independent variables and the assigned TADS, FADS, LADS, and

BADS scores are the dependent variables. Thus the analysis is examining where there is a significant relationship between known PMSL/logADD and TADS, FADS, LADS, and BADS for both Heaton et al. and van Daalen et al. that would indicate that the scoring systems can be used to predict unknown PMSI. Since the donors used for this study were all placed in the same general location, the "swamp", and within similar conditions, it was assumed for this analysis that all donors used for this study were subjected to the same environmental circumstances.

Lastly, comparative statistics were performed to test the extent to which the predicted PMSI based on a predicted ADD aligned with the known PSMI utilizing the predictive regression model published by Heaton et al..

$$predictedADD = 10\frac{(TADS + 3.706)}{7.778}$$

This was done only for the scores derived from the Heaton et al. TADS system as van Daalen et al. did not include a regression formula or predictive model in their published results. Additionally, even if van Daalen et al. had included a predictive model in their published results it would not be viable for use with this analysis because it would not include ADD as a variable. Heaton et al.'s predictive ADD based on the TADS chart can be found in appendix II. Since Heaton et al. used Celcius while collecting their temperature data, before the current ADD could be compared it was converted from Fahrenheit to Celcius so as to be compatible with the published methods. Once converted to Celcius, the ADD of each donor was compared to the predicted ADD in the chart based on the corresponding TADS score. ADD was then back calculated for those samples who fell within the 95% confidence interval of the Heaton et al.. To this aim the average daily temperature of the day from which the remains were scored were added to the average daily temperature of the previous days until a value approximately equal to the estimated ADD was reached. The number of days it takes to reach this value is the estimated PMSI. This was done to explore exactly how close, in days, Heaton et al.'s calculated ADD and PMSI was to the actual ADD and PMSI.

Results

Interobserver Agreement

Two donors were excluded from this interobserver agreement analysis due to inconclusive/missing scoring results (n=7). For the Heaton et al. scoring system, the result of Fleiss' Kappa suggests that there is a fair amount of agreement between the observers using this system $\kappa=0.311$ (95% CI, 0.272 to 0.350), $p < .0005$. The guidelines used to assess the strength of agreement are based on values derived from Cohen's kappa coefficient from Altman (1999) which had been adapted from Landis and Koch (1977). For the van Daalen et al. TADS system the result of Fleiss' Kappa suggests that there is a poor amount of agreement between the observers using this system $\kappa=0.149$ (95% CI, 0.121 to 0.177), $p < .0005$. In addition to these results, three of the observers reported that they found difficulty with both scoring systems due to a lack of options that they felt best represented the stages of decomposition displayed in the images provided. However, two observers also reported that between the two TADS systems, Heaton et al. was easier to use and more streamlined in comparison to van Daalen et al.. The results of the interobserver agreement analysis suggest that, in terms of accuracy and usability, the Heaton et al. TADS system was best able to produce consistent results from multiple observers.

Regression Analysis

Tables 2 and 3 and figures 1 – 8 display the results of the regression analysis. The results of the regression analysis show that only Heaton et al.'s TADS, BADS, and LADS, and van

Table 2 – *Heaton et al. Multilinear Regression Results*

Heaton et al.					
	R	R Squared	F(2,6)	*p* -value	Unstandardized Beta Co
TADS	0.852	0.726	7.956	0.021	17.943
FADS	0.411	0.169	0.609	0.575	-12.628
BADS	0.870	0.757	9.365	0.014	-47.711
LADS	0.909	0.825	14.190	0.005	-56.732

Table 3 – *van Daalen et al. Multilinear Regression Results*

van Daalen et al.					
	R	R Squared	F(2,6)	*p* -value	Unstandardized Beta Co
TADS	0.742	0.551	3.676	0.091	-57.191
FADS	0.472	0.222	0.858	0.470	-12.639
BADS	0.740	0.548	3.640	0.092	-20.87
LADS	0.888	0.788	11.174	0.009	-23.682

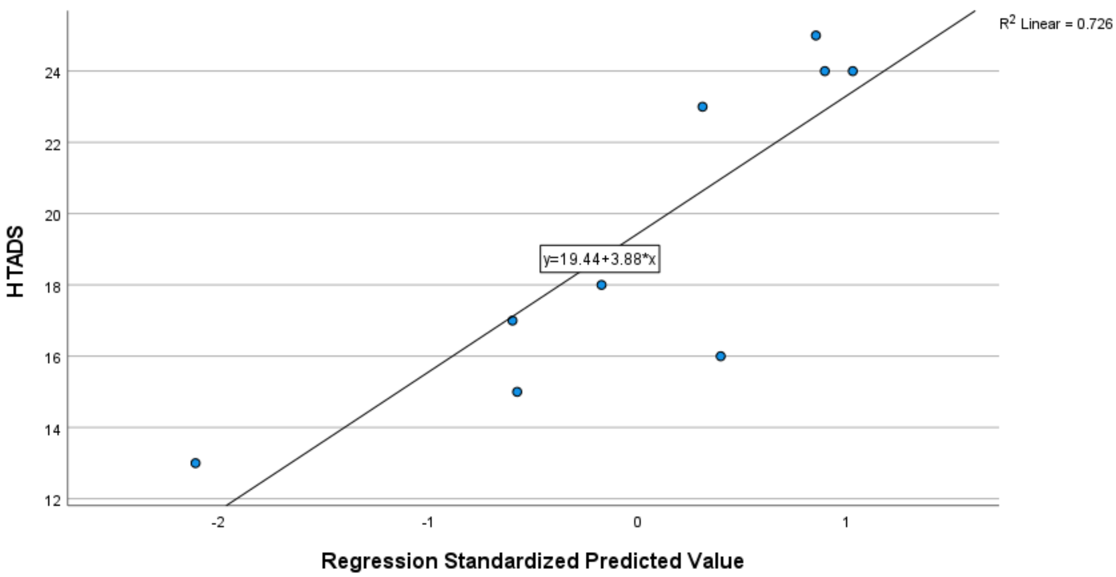

Figure 1: Scatterplot depicting the relationship between the TADS scores produced using the Heaton et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

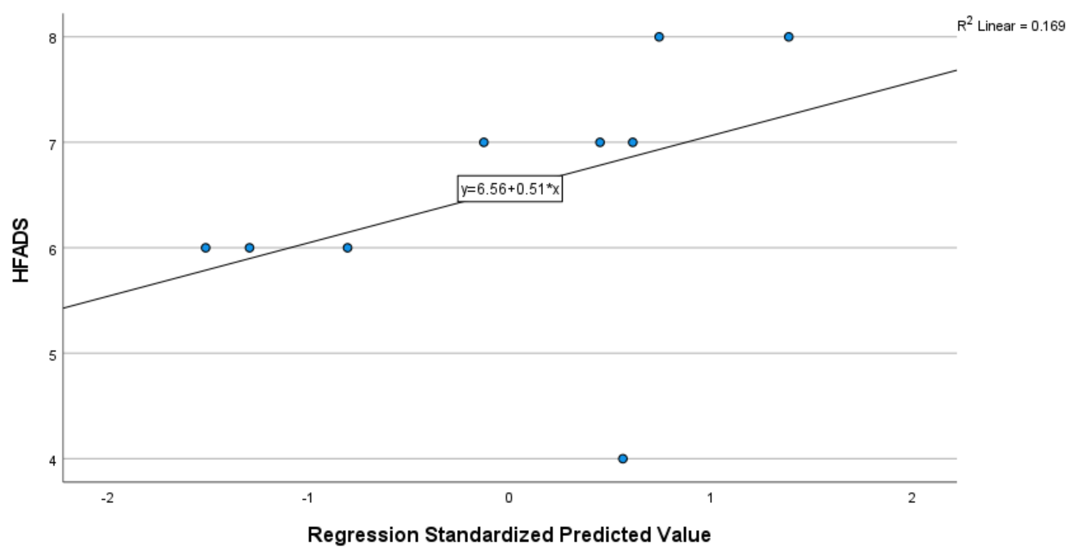

Figure 2: Scatterplot depicting the relationship between the FADS scores produced using the Heaton et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

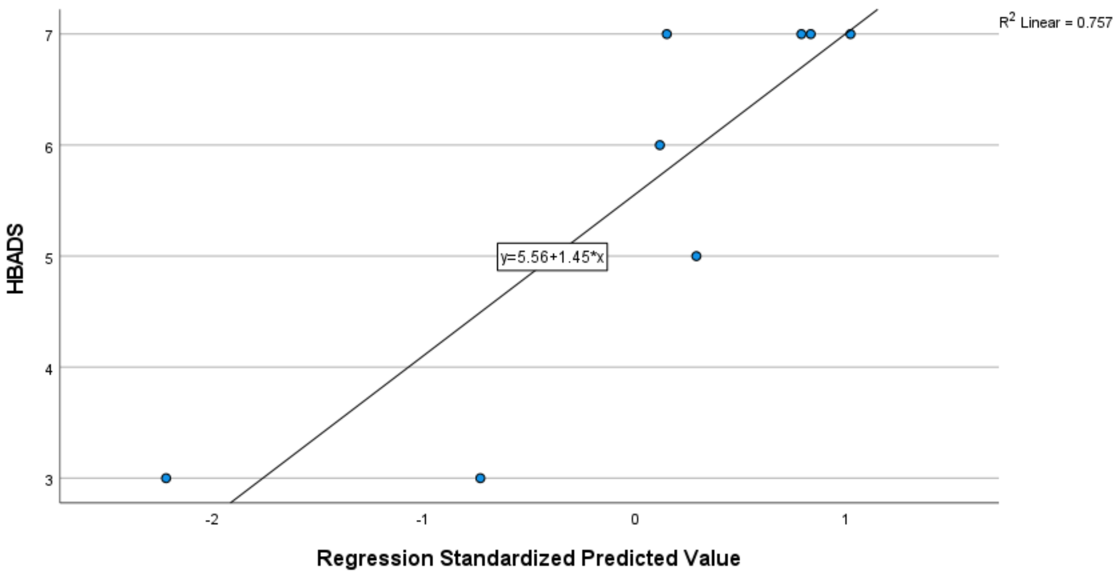

Figure 3: Scatterplot depicting the relationship between the BADS scores produced using the Heaton et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

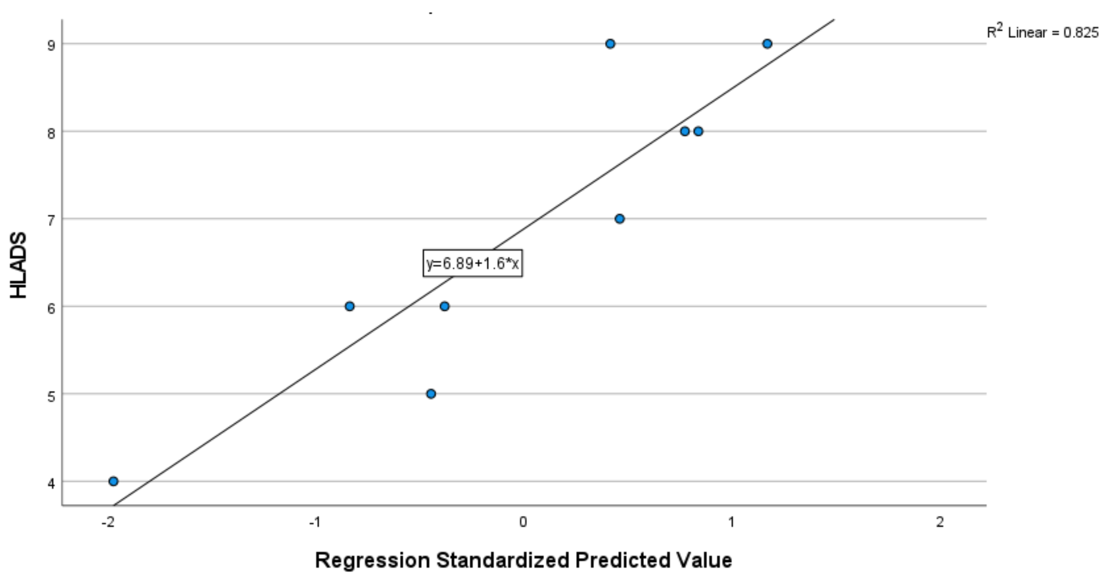

Figure 4: Scatterplot depicting the relationship between the LADS scores produced using the Heaton et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

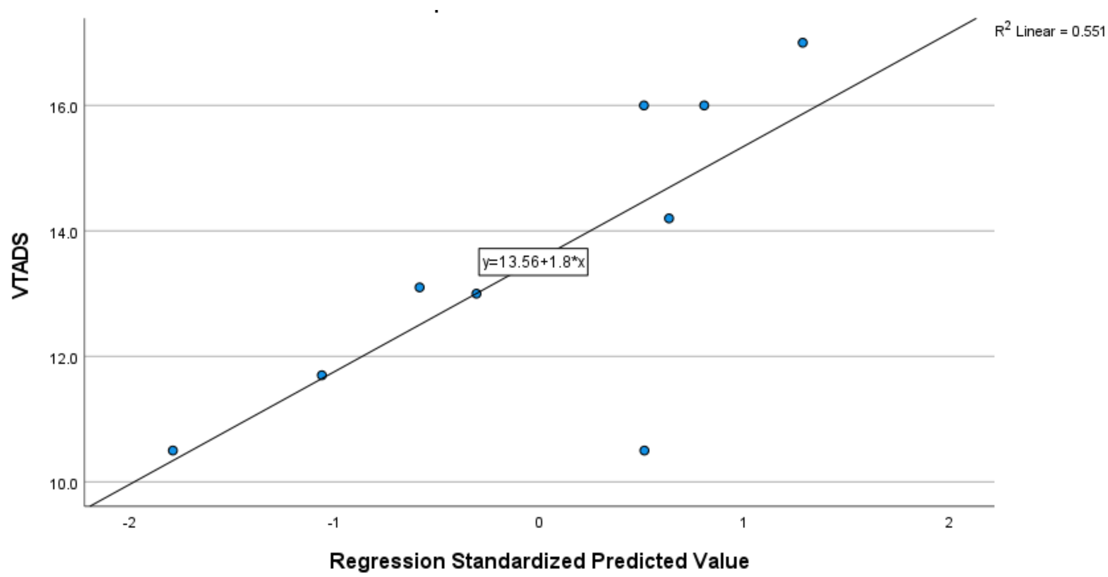

Figure 5: Scatterplot depicting the relationship between the TADS scores produced using the van Daalen et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

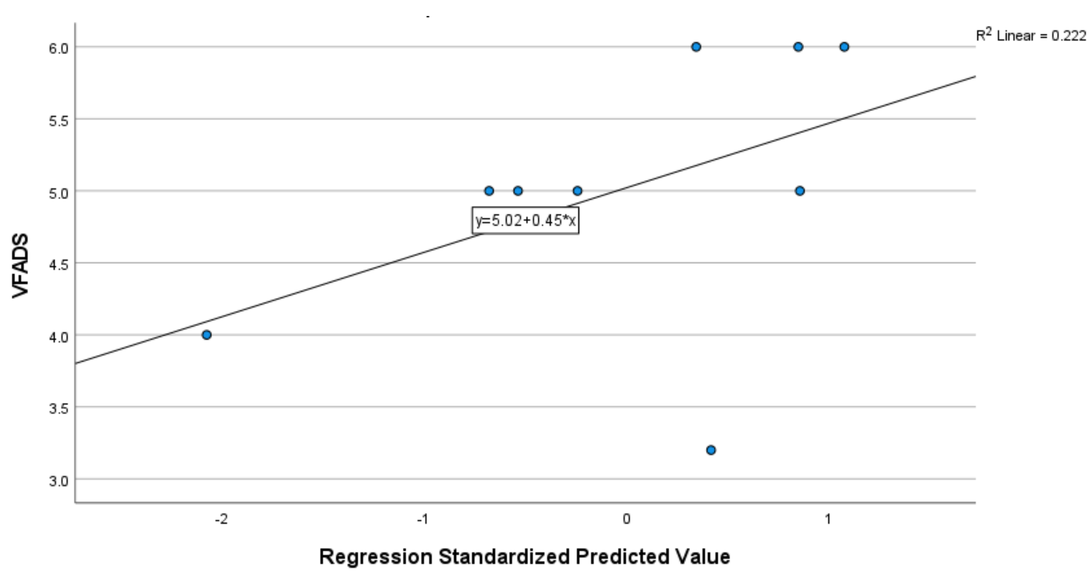

Figure 6: Scatterplot depicting the relationship between the FADS scores produced using the van Daalen et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

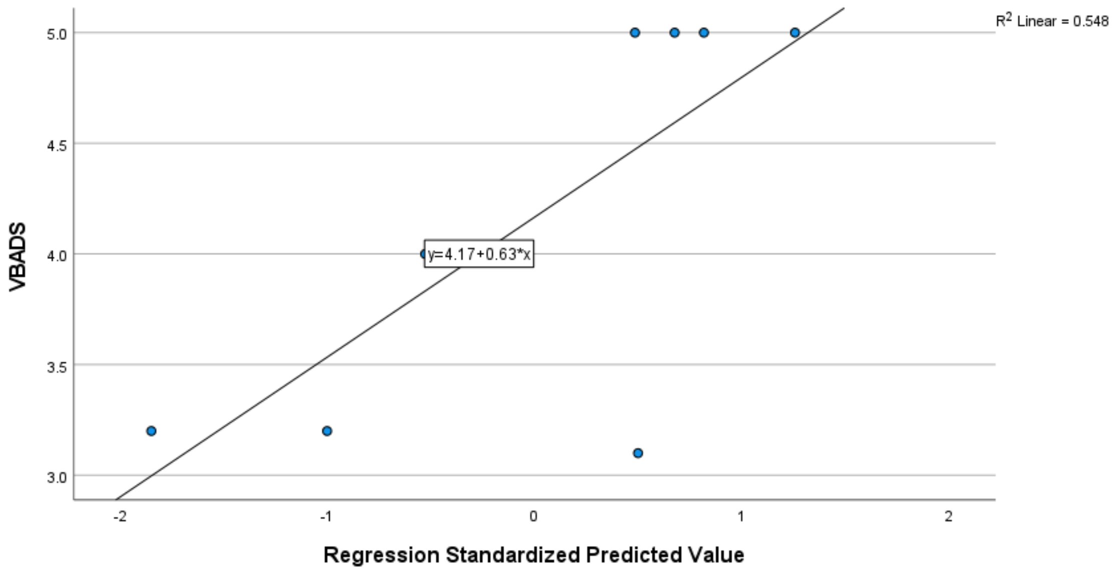

Figure 7: Scatterplot depicting the relationship between the BADS scores produced using the van Daalen et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

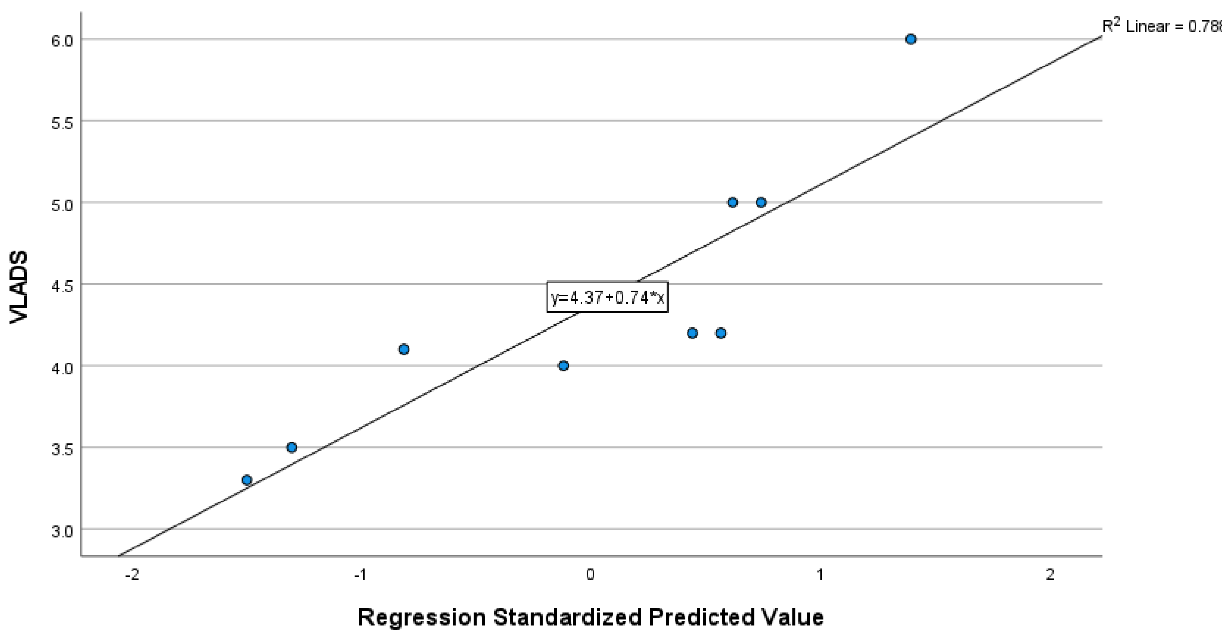

Figure 8: Scatterplot depicting the relationship between the LADS scores produced using the van Daalen et al. scoring system and the predicted dependent variable value from the combined PMSI and logADD.

Table 4 – *Heaton et al. Comparative Analysis of Predicted Versus Actual ADD in Celsius*

Donors	TADS	PMSI	ADD (C)	Predicted ADD (C)	Falls within 95% CI	Calculated ADD	Predicted PMSI
D19-013	23	8	222.4	2714	no		
D19-014	24	19	548.7	3649	no		
D19-015	15	6	168.6	254.1	yes	250	9
D19-016	18	22	611.1	617.7	yes	611.1	22
D19-017	24	7	228.2	3649	no		
D19-020	13	4	113.5	140.6	yes	141	5
D19-021	25	14	358.9	4906	no		
D19-022	16	10	243.3	341.7	yes	340.6	14
D19-023	17	23	550.3	459.4	yes	442.1	20

Daalen et al.'s LADS found any statistical significance between their assigned aquatic decomposition scores and PMSI and logADD. Alternatively, Heaton et al.'s FADS and van Daalen et al.'s TADS, FADS, and BADS were not found to be statistically significant. However, as can be seen in the figures above, all of the Heaton et al. and van Daalen et al. systems possess a positive linear relationship with PMSI/logADD, though the strength of these relationships are highly variable. This variability may be due to the presence of outliers; however, it could also potentially be attributed to the small number of individuals in this sample. While this analysis was performed with a small sample size, and thus more open to error, these findings suggest which areas of the TADS systems might be impacting the relationship, or lack thereof, between the TADS scores and PMSI and ADD.

<u>Comparative Analysis</u>

Table 4 depicts the results of the comparative analysis. Again, this analysis was only conducted using the Heaton et al. method because van Daalen et al. did not include the regression equation or predictive model in their published results. In this table *Predicted ADD* refers to the ADD acquired from Heaton et al.'s predictive chart and the *Calculated ADD* refers to the value that was determined by adding the average temperature of each day, starting from the known PMSI, and going backwards until a number is reached that is close to the predicted ADD. *Predicted PMSI* refers to the PMSI that was calculated by adding the total amount of days it took to achieve the calculated ADD. ADD was not calculated for those donors whose predicted ADD greatly exceeded their actual ADD. This was because the predicted ADD for these individuals was up to sixteen times larger than the actual ADD despite there being no drastic increases or decreases in temperature. Thus, the calculated ADD and predicted PMSI would, in accordance with the predicted ADD, far exceed the actual ADD and PMSI. Out of the nine donors included in this sample, Heaton et al.'s TADS system was able to predict the ADD of five donors with a range of error between 4 - 0 days. Out of these five donors, four had ADD slightly overpredicted by their TADS score and one was slightly underpredicted. Comparatively, the other four samples, that are highlighted in the above table, were greatly overpredicted by their TADS score and did not fall within the 95% confidence intervals set by Heaton et al., all of which possessed TADS scores above 20.

Discussion

The results of the regression analysis suggest that there are certain areas of both TADS systems that could use alterations so as to better accommodate the specifics of aquatic decomposition in the types of environments found within Florida. Specifically, Heaton et al.'s FADS and van Daalen et al.'s FADS, and BADS as all were found to lack statistical significance. Thus, there cannot be said to be direct evidence of an impactful relationship between these specific systems and PMSI/ADD that is not impacted by chance. Though it should be noted that even though Heaton et al.'s FADS was found to lack statistical significance, the overall TADS system did not. Additionally, throughout the process of scoring, the author noted that there were several occasions where the facial decomposition appeared to be progressing at a faster rate than the decomposition of the rest of the body. These observations could indicate that aquatic facial decomposition may occur at a different, or faster, rate in a sub-tropic environment compared to a temperate one which in turn would impact how an individual would be scored using either TADS system. It is possible that this potential difference in decomposition time impacts the remains further on in the decomposition process, namely the mid to advanced stages. If true, this could potentially be an important factor as to why the comparative analysis shows a lack of accuracy for those individuals who possessed a TADS score over 20. However, the extent to which these discrepancies may impact the overall TADS calculation is currently unknown. The specifics behind why there was an increased rate of decomposition for some of the samples and not others are unknown, however further research into this phenomenon could provide insight as to how best to improve this method. While further research into the relationship between the TADS systems and PMSI/ADD is necessary to draw more concrete conclusions, the results of the regression analysis indicate that the Heaton et al. TADS system may be better suited for use within a subtropic environment in comparison to the van Daalen et al. TADS system.

A seen in the comparative analysis, the four samples that failed to fall within the confidence interval set up by Heaton et al. all possessed TADS scores over 20, which, according to Heaton et al., was the greatest value used to create their predictive model. When Heaton et al. produced their original regression analysis, their sample population was lacking in individuals considered to be in a more advanced stage of decomposition. Thus, when creating their predictive model based on their regression equation the predictive scores above 20 were found by following the score/ADD pattern established for TADS scores under 20. The predicted model for TADS scores 21 - 25 were thus extrapolated and acknowledged by the authors to be tenuous. It is possible that because of this the remains with TADS scores greater than 20 are unable to be predicted accurately within the environments in question; suggesting that the issues found with the reliability of the scoring systems lie with the more advanced stages of decomposition. While not possible given the current sample size it is hypothesized by the author that the strength of the relationship between the scoring systems overall and PMSI/logADD would be improved if all individuals with TADS scores over 20 were removed from the sample. In general, the current study suggests that remains with a TADS score under 20 can have their ADD, and thus PMSI, predicted with a relative degree of accuracy using the methods developed by Heaton et al.; further research concerning advanced stages of decomposition is necessary to improve this method for remains with a TADS score above 20.

While all of the donors used for this study were placed within the same area without clothing, there are several differences that could have potentially impacted the rate of decomposition that must be addressed. The largest potential difference that could have impacted the vast differences in decomposition is the extent to which the remains were actually submerged. Due to the nature of an ephemeral wetland, the water level throughout the duration of the active decomposition processes was highly variable, meaning that not all of the donors were submerged to the same extent for the same duration of time. Thus, some donors would have been subjected to factors more commonly associated with terrestrial decomposition, such as flies and other insects that would not affect fully submerged remains, more than others that could impact the rate of decomposition. Additionally, each donor was not placed with the same covering type when originally deposited at USF-FORT. Three donors were contained within PVC and orange construction netting cages, two were contained within partial mesh cages that did not possess a top, one was placed with no cage at all, and the final two were placed under a combination of plastic tarp and wire mesh. The exact impacts of these factors as a whole or individually are unknown, however, there was no evidence that one of these containment types meaningly impacted decomposition in that no one containment type was associated with those individuals whose ADD and PMSI was not able to be predicted in the comparative analysis. While the lack of an observable relationship between the donors and their housing suggest that these containment strategies were not influential enough to cause the differences seen in the data alone, further research into the impact of caging types within scenarios such as this would need to be explored further to test this claim.

Since this study utilized data recorded several years before this project began and the author arrived at USF-FORT, the author had no input into where or how the donors in question were placed at the facility. In an ideal iteration of this project, factors such as water level at time of placement and housing type would have been standardized in order to eliminate potential confounding variables. While it is believed that these differences did not overtly impact the decomposition of these individuals, further research on the subject in the future would greatly benefit from a regimented placement strategy.

Another factor that could have impacted the rates of decomposition in these samples was the presence or absence of scavenger activity, specifically from vultures, in the period before the assigned known PMSI. While the ephemeral swamp at USF-FORT does not possess the types of aquatic scavengers discussed previously in the literature review, it is inhabited by several species that have been found in relation to the remains themselves. In terms of aquatic or semiaquatic creatures the most prevalent were snakes and small turtles, however, while their presence was noted it is unknown to what extent their activities interacted with the decomposing remains. While the potential impacts of these smaller creatures are unknown, other scavengers were known to scavenge the remains Throughout their duration at USF-FORT, it is known that all nine of the donors used in this study experienced scavenging by vultures, largely from the American black vulture. At the time of their selected known PMSI only four of the donors had undergone active scavenging by vultures, three of which are included in the subset of samples whose predicted ADD did not fall within the 95% confidence interval of the Heaton et al. calculated ADD. This could be seen as suggesting that the presence of vulture scavenging increased the rate of decomposition, thus adding to the potential explanation as to why the Heaton et al. TADS system failed to achieve significant results for four of the sample donors. However, because there was one donor who failed to achieve significance who was not scavenged by vultures at the time of their known PMSI and one donor who achieved significance that was scavenged before the point of their known PMSI it is impossible to draw any conclusion as to the definite impacts of vulture scavenging on aquatic decomposition. While these results suggest possible significant interaction, further testing is required to confirm whether vulture scavenging alone is enough to affect the rate of aquatic decomposition.

In addition to scavengers, the formation of adipocere is highly probable when decomposing remains are exposed to waterlogged environments. While the formation of adipocere was not noted by the author in the photographs used to score the remains that does not necessarily mean that adipocere had not begun to form in areas that were just not visual in the images. It is known that after their retrieval from USF-FORT the donors used for this study did possess varied amounts of adipocere formation. Though it is unknown at what point this adipocere formed there is a chance that the saponification process was already underway by the time of each donors scoring date. Meaning that for wherever saponification had started, the decomposition timeline would technically be considered complete once the adipocere had formed since adipocere itself acts as a preserving agent for tissue that it surrounds. This also highlights a key issue inherent to visual scorings systems such as the two discussed here; you can only score what you actually see. While the formation of adipocere may have had no impact on the scoring of the donors, further research on the specifics of adipocere formation in relation to visual score based PMSI estimation methods is necessary to eliminate it as a concern for areas of potential interference.

The largest limitation to the current study is the sample size available. While the current findings suggest that the Heaton et al. method could be employed for use with remains found within ephemeral aquatic environments within the state of Florida and other similar ecosystems for cases that achieve a TADS score under 20, further testing with a larger sample size is needed to confirm these conclusions. Additionally, further testing on a larger sample size is also necessary to draw conclusions on the viability of van Daalen et al.'s methods since they did not include a predictive model with their published results. Though the current study does suggest that even with a larger sample size, Heaton et al.'s method would still be preferable to the methods of van Daalen et al. in terms of significance and ease of use across different observers. In addition to a larger sample size, further testing would need to be performed utilizing data from different types of aquatic environments found within Florida to confirm that there are no significant differences caused by differing ecosystems, though the results of Palazzo et al. (2020 and 2021) suggest that, at least in terms of salt versus fresh water, there is unlikely to be a significant difference.

Conclusion

This study serves to illuminate the potential for PMSI estimation methods that utilize visual taphonomic changes in cases of decomposition within ephemeral aquatic environments within the state of Florida. While the current study would need to be replicated utilizing a larger sample size, it is the opinion of the author that the TADS system of Heaton et al. shows a reliable degree of accuracy in estimating PMSI in cases where the TADS score is below 20 in the climate in question. Further research on decomposition from cases with scores above 20 is necessary to potentially allow for use of this methodology with remains found in an advanced stage of decomposition who would have a TADS score above 20. For remains found in an advanced stage of decomposition, it is possible that the methods put forth by Heaton et al. may be viable for use within the current region in question if the scoring system itself is modified; however, it is also possible that this method for estimating PMSI based on decomposition scores is just not viable for advanced decomposition. This is most likely due to the fact that as the decomposition process enters an advanced stage it also slows down to a pace that is relatively unpredictable in comparison to earlier stages until eventually reaching the point where decomposition is considered to be finished. Generally, this is at the point of skeletonization, mummification, or saponification. As remains enter an advanced stage of decomposition the expected steps they will take towards skeletonization no longer follow highly predictable timelines, making their ability to be used to predict PMSI less practicable. This is even more so in cases of saponification where, as discussed previously, the formation of adipocere is considered to essentially end the decomposition process and can preserve remains for thousands of years.

Due to the lack of comparable data for van Daalen et al., no direct conclusions can be made about the applicability of these methods at this time. Further testing on larger sample populations may prove that this method is reliable for use within a subtropic climate, however the current study does not support this. Even if found to be overall reliable, it is highly probable that the issues seen using the Heaton et al. system with estimating PMSI for individuals in an advanced state of decomposition would also be seen using the van Daalen et al. system. This is because while both systems were created using data from two different locations, both are considered to be temperate in climate. Thus, while not definite, it is likely that they may experience similar issues.

While the current study did not look specifically at the impacts of scavenging on decomposition in these conditions and thus the impact of scavenging on PMSI estimation, further research into the subject can only be beneficial to improving the methods currently used and available for this estimation. This is specifically important in the case of vultures scavenging from waterlogged remains as the current literature on the subject is limited at best in comparison to other aquatic scavengers. Additional research investigating the specifics of the impacts of vulture scavenging in cases of semi-aquatic decomposition would also serve to benefit the potential accuracy of these methods, specifically in terms of whether their presence accelerates the decomposition process in a manner that would cause the TADS system to be unreliable.

Overall, the results of the current study are an important step in improving PMSI estimation methods for use within aquatic environments in Florida because it illustrates that a decomposition scoring system methodology can be used to estimate PMSI when used in combination with ADD for remains found in the early to mid-stages of decomposition. This ability to significantly estimate PMSI means that this method can reliably be used by experts like forensic anthropologists in cases where they may be implored to assist with a medicolegal or criminal investigation even in situations where the only data available are photographic images of the remains. Thus the methods explored in this paper can be used by anthropologists in an actively applied manner to determine an estimate of how long a set of remains have been left to decompose in a body of water.

Works Cited

Altman, D. G. (1999). *Practical statistics for medical research*. New York: Chapman & Hall/CRC Press.

Anderson, G. and L. Bell. (2014). Deep Coastal Marine Taphonomy: Investigation into Carcass Decomposition in the Saanich Inlet, British Columbia Using a Baited Camera. PLoS ONE, 9(10), 1-25.

Anderson, G. and L. Bell. (2017). Comparison of Faunal Scavenging of Submerged Carrion in Two Seasons at a Depth of 170 m, in the Strait of Georgia, British Columbia. Insects, 8(1), 33-47.

Armelagos, G. (2014). Brain Evolution, the Determinants of Food Choice, and the Omnivore's Dilemma. Critical Reviews in Food Science and Nutrition, 54, 1330–1341.

Armstrong, Erica J. and Kevin L. Erskine. (2018). Investigation of Drowning Deaths: A Practical Review. Academic Forensic Pathology, 8(1), 8-43.

Cartozzo, C., T. Simmons, J. Swall, and B. Singh. (2021). Postmortem submersion interval (PMSI) estimation from the microbiome of Sus scrofa bone in a freshwater river. Forensic Science International, 318, 110480.

Caruso, J. L. (2016) Decomposition Changes in Bodies Recovered from Water. Academic Forensic Pathology, 6(1), 19-27.

Castillo, J.J., Z. S. Hazlett, R. A. Orlando, & Garver, W. S. Garver. (2017). A Global Evolutionary and Metabolic Analysis of Human Obesity Gene Risk Variants. Gene, 627, 412-419.

Christensen, A. M. and S. W. Myers. (2011). Macroscopic Observations of the Effects of Varying Fresh Water pH on Bone. Journal of Forensic Sciences, 56(2), 475-479.

Dalal, J., S. Sharma, T. Bhardwaj, S. K. Dhattarwal, and K. Verma. (2020). Seasonal study of the decomposition pattern and insects on a submerged pig cadaver. Journal of Forensic and Legal Medicine, 74, 102023

Fleiss, J. L. (1971). Measuring nominal scale agreement among many raters. *Psychological Bulletin*, *76*, 378-382.

Fleiss, J. L., B. Levin, and M. C. Paik. (2003). *Statistical methods for rates and proportions* (3rd ed.). Hoboken, NJ: Wiley.

Heaton, V., A. Lagden, C. Moffatt, and T. Simmons. (2010). Predicting the Postmortem Submersion Interval for Human Remains Recovered from U.K. Waterways. Journal of Forensic Sciences, 55(2), 302-307.

Humphreys, M. K., E. Panacek, W. Green, and E. Albers. (2013). Comparison of Protocols for Measuring and Calculating Postmortem Submersion Intervals for Human Analogs in Fresh Water. Journal of Forensic Sciences, 58(2), 513-517.

Hyun, C., H. Kim, S. Ryu, and W. Kim. (2019). Preliminary study on microeukaryotic community analysis using NGS technology to determine postmortem submersion interval (PMSI) in the drowned pig. Journal of Microbiology, 57(11), 1003–1011

Katzmarzyk, P. and W. Leonard. (1998). Climatic Influences on Human Body Size and Proportions: Ecological Adaptations and Secular Trends. American Journal of Physical Anthropology, 106, 483–503.

Landis, J. R., & G. G. Koch. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*, 159-174.

Leonard, W. (2012). Chapter 7: Human Nutritional Evolution. In Human Biology: An Evolutionary and Biocultural Perspective, Second Edition, S. Stinson, B. Bogin, and D. O'Rourke eds. John Wiley & Sons, Inc.

Lunetta, P., A. Zaferes, and J. Modell. (2014). Establishing the Cause and Manner of Death for Bodies Found in Water. In Drowning, edited by J. Bierens, p.1179-1189. Springer.

Macfarlane, D., F. Nelson, M. B. Hudson, and H. Murphy. (2020). Using measures of water quality to narrow down the postmortem submersion interval (PMSI) in water. Environmental Earth Sciences, 79, 50.

Magni, P. A., J. Lawn, and E. E. Guareschi. (2021). A practical review of adipocere: Key findings, case studies and operational considerations from crime scene to autopsy. Journal of Forensic and Legal Medicine, 78, 102109.

Magni, P. A., Elysia Tingeya, Nicola J. Armstrong, and Jennifer Verduin. (2021). Evaluation of barnacle (Crustacea: Cirripedia) colonisation on different fabrics to support the estimation of the time spent in water by human remains. Forensic Science International, 318, 110526.

Megyesi, M. S., S. P. Nawrocki, and N. H. Haskel. (2005). Using accumulated degree-days to estimate the post mortem interval from decomposed human remains. Journal of Forensic Sciences, 50, 1-9.

O'Brien, T. G., and A. C. Kuehner. (2007). Waxing Grave About Adipocere: Soft Tissue Change in an Aquatic Context. Journal of Forensic Sciences, 52(2), 294-301.

Palazzo, C., G. Pelletti, P. Fais, R. Boscolo-Berto, F. Fersini, R. M. Gaudio, and S. Pelotti. (2020). Postmortem submersion interval in human bodies recovered from fresh water in an area of Mediterranean climate. Application and comparison of preexisting models. Forensic Science International, 306.

Palazzo, C., G. Pelletti, P. Fais, A. Giorgetti, R. Boscolo-Berto, R. M. Gaudio, F. Pirani, A. Tagliabracci, and S. Pelotti. (2021). Application of aquatic decomposition scores for the determination of the Post Mortem Submersion Interval on human bodies recovered from the Northern Adriatic Sea. Forensic Science International, 318.

Palmer, C. (2020). Estimating the Impact of Laminar Flow on the Pattern and Rate of Decomposition in Aquatic Environments—Is There a Better Way of Modeling Decomposition? Journal of Forensic Sciences, 65(5), 1601-1609.

Roberts, L. G., J. R. Spencer, & G. R. Dabbs. (2017). The Effect of Body Mass on Outdoor Adult Human Decomposition. Journal of Forensic Sciences, 62(5), 1145-1150.

Ruff, C.. (2002) Variation in Human Body Size and Shape. Annual Review of Anthropology, 31, 211-32

Sutherland, A., J. Myburgh, M. Steyn, and P. J. Becker. (2013). The effect of body size on the rate of decomposition in a temperate region of South Africa. Forensic Science International, 231, 257–262.

Sutton, L. and J. Byrd. (2020). An introduction to postmortem interval estimation in medicolegal death investigations. Wiley Interdisciplinary Reviews: Forensic Science, 2(5), 1-10.

Wallace, J. R., R. W. Merritt, R. Kimbirauskas, E. M. Benbow and M. McIntosh. (2008). Caddisflies Assist with Homicide Case: Determining a Postmortem Submersion Interval Using Aquatic Insects. Journal of Forensic Sciences, 531(1), 219-221.

Means, R. P. M. and D. A. Johnson. (2008) Florida's Ephemeral Ponds and Pond-Breeding Amphibians. Coastal Plains Institute; Tallahassee, FL.

National Resources Conservation Service. (2007) Temporarily Flooded Wetlands. Fish and Wildlife Habitat Management Leaflet, 47.

NOAA Office for Coastal Management. Shoreline Mileage of the United States. Electronically accessed. coast.noaa.gov/data/docs/states/shorelines.pdf

Water Science School. (2018) How Wet is Your State? The Water Area of Each State. U.S. Geological Survey. Electronically accessed. usgs.gov/special-topics/water-science-school/science/how-wet-your-state-water-area-each-state

Widya, M., C. Moffatt, and T. Simmons. (2012). The Formation of Early Stage Adipocere in Submerged Remains: A Preliminary Experimental Study. Journal of Forensic Science, 57(2), 328-333.

van Daalen, M., D. de Kat, B. O. Grotebevelsborg, R. de Leeuwe, J. Warnaar, R. J. Oostra, and W. Duijst-Heesters. (2017). An Aquatic Decomposition Scoring Method to Potentially Predict the Postmortem Submersion Interval of Bodies Recovered from the North Sea. Journal of Forensic Sciences, 62(2), 369-373.

Appendix I: Total Aquatic Decomposition Scoring Systems

Heaton et al. TADS

Table 5 – *Descriptive stages for decomposition observed in the face and the assigned facial aquatic decompositional score (FADS) reproduced from Heaton et al. 2010*

FADS	Score Description
1	No visible changes
2	Slight pink discoloration, darkened lips, goose pimpling
3	Reddening of the face and neck, marbling visible on face. Possible early signs of animal activity/predation--concentrated on the ears, nose, and lips
4	Bloating of the face, green discoloration, skin beginning to slough off
5	Head hair beginning to slough off--mostly at front. Brain softening and becoming liquified. Tissue becoming exposed on the face ans neck. Green/black discoloration
6	Bone becoming exposed—concentrated over the orbital, frontal, and parietal regions. Some on the mandible and maxilla. Early adipocere formation
7	More extensive skeletonization on the cranium. Disarticulation of the mandible
8	Complete disarticulation of the skull from torso. Extensive adipocere formation

Table 6 – *Descriptive stages for decomposition observed in the body and the assigned body aquatic decompositional score (BADS) reproduced from Heaton et al. 2010*

BADS	Score Description
1	No visible changes
2	Slight pink discoloration, goose pimpling
3	Yellow ⁄ green discoloration of abdomen and upper chest. Marbling. Internal organs beginning to decompose ⁄ autolysis
4	Dark green discoloration of abdomen, mild bloating of abdomen, initial skin slippage
5	Green ⁄ purple discoloration, extensive abdominal bloating—tense to touch, swollen scrotum in males, exposure of underlying fat and tissues
6	Black discoloration, bloating becoming softer, initial exposure of internal organs and bones
7	Further loss of tissues and organs, more bone exposed, initial adipocere formation
8	Complete skeletonization and disarticulation

Table 7 – *Descriptive stages for decomposition observed in the limbs and the assigned limb aquatic decompositional score (LADS) reproduced from Heaton et al. 2010*

LADS	Score Description
1	No visible changes
2	Mild wrinkling of skin on hands and / or feet. Possible goose pimpling
3	Skin on palms of hands and / or soles of feet becoming white, wrinkled, and thickened. Slight pink discoloration of arms and legs.
4	Skin on palms of hands and / or soles of feet becoming soggy and loose. Marbling of the limbs—predominantly on upper arms and legs
5	Skin on hands/ feet starting to slough off. Yellow / green to green / black discoloration on arms and / or legs. Initial skin slippage on arms and / or legs
6	Degloving of hands and / or feet—exposing large areas of underlying muscles and tendons. Patchy sloughing of skin on arms and / or legs
7	Exposure of bones of hands and / or feet. Muscles, tendons, and small areas of bone exposed in lower arms and / or legs
8	Bones of hands and / or feet beginning to disarticulate. Bones of upper arms and / or legs becoming exposed
9	Complete skeletonization and disarticulation of limbs

van Daalen et al. TADS

Table 8 – *Descriptive stages for decomposition observed in the face and the assigned facial aquatic decompositional score (FADS) reproduced from van Daalen et al. 2017*

FADS	Score Description
1	1.1 No visible changes
2	2.1 Marbling and/or 2.2 Skin slippage and/or 2.3 Hair sloughs off
3	3.1 Bloating of eyelids and/or 3.2 Bloating of lips
4	4.1 Gray, matte discoloration of the skin with a crumbly surface
5	5.1 Partial skeletonization
6	6.1 Complete skeletonization

Table 9 – *Descriptive stages for decomposition observed in the body and the assigned body aquatic decompositional score (BADS) reproduced from van Daalen et al. 2017*

BADS	Score Description
1	1.1 No visible changes
2	2.1 Marbling of upper trunk and/or 2.2 Marbling of lower trunk and/or 2.2 Skin slippage and/or 2.3 Hair sloughs off
3	3.1 Bloating of abdomen and/or 3.2 Bloating of genitals
4	4.1 Gray, matte discoloration of the skin with a crumbly surface
5	5.1 Partial skeletonization
6	6.1 Complete skeletonization

Table 10 – *Descriptive stages for decomposition observed in the limbs and the assigned limb aquatic decompositional score (LADS) reproduced from van Daalen et al. 2017*

LADS	Score Description
1	1.1 No visible changes
2	2.1 Wrinkling and/or white discoloration of the skin of hands and/or feet
3	3.1 Marbling and/or 3.2 Skin slippage and/or 3.3 Hair sloughs off and/or 3.4 Degloving and/or 3.5 Absence of nails
4	4.1 Gray, matte discoloration of the skin with a crumbly surface 4.2 Partial and/or gross skeletonization of the distal part of the limbs (hands and/or feet) 4.3 Partial skeletonization of the more proximal parts of the limbs (arms and/or legs)
5	5.1 Partial skeletonization
6	6.1 Complete skeletonization

Appendix II: Heaton et al. Predictive Table

Table 11 – *Total aquatic decomposition score (TADS) and the predicted accumulated degree days (ADD) and confidence intervals, back transformed from the logarithmic model reproduced from Heaton et al. 2010*

TADS	Predicted ADD	Lower 95% Confidence Interval	Upper 95% Confidence Interval
5	13.16	3.55	45.88
6	17.7	4.825	61.52
7	23.79	6.552	82.58
8	31.99	8.889	110.9
9	43.01	12.05	149.2
10	57.83	16.31	200.8
11	77.76	22.07	270.5
12	104.5	29.82	364.9
13	140.6	40.26	492.6
14	189	54.31	665.5
15	254.1	73.18	900.3
16	341.7	98.51	1219
17	459.4	132.5	1652
18	617.7	178	2241
19	830.5	238.9	3043
20	1117	320.4	4135
21	1501	429.3	5625
22	2019	574.7	7659
23	2714	768.6	10437
24	3649	1027	14235
25	4906	1371	19432

Appendix III: Raw Data

Table 12 - *Unaltered Data and TADS Scores*

Donor	Placement date	Pickup date	Selected Date	H TADS	HFADS	HBADS	HLADS	VTADS	VFADS	VBADS	VLADS
D19-013	7/3/2019	10/14/2019	7/10/2019	23	7	7	9	16.0	6.0	5.0	5.0
D19-014	7/12/2019	8/12/2019	7/31/2019	24	7	7	8	14.2	5.0	5.0	4.2
D19-015	7/12/2019	10/7/2019	7/17/2019	15	7	3	5	13.0	5.0	4.0	4.0
D19-016	7/24/2019	3/15/2021	8/14/2019	18	6	6	6	13.1	5.0	4.0	4.1
D19-017	8/5/2019	9/20/2019	8/12/2019	24	8	7	9	17.0	6.0	5.0	6.0
D19-020	8/20/2019	9/23/2019	8/23/2019	13	6	3	4	10.5	4.0	3.2	3.3
D19-021	10/1/2019	6/1/2020	10/14/2019	25	8	7	8	16.0	6.0	5.0	5.0
D19-022	10/15/2019	3/15/2021	10/24/2019	16	4	5	7	10.5	3.2	3.1	4.2
D19-023	10/22/2019	3/15/2021	11/13/2019	17	6	5	6	11.7	5.0	3.2	3.5

Appendix IV: Permissions for Reproduction of Tables 5-11

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