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Pig Decomposition in Lotic Aquatic Systems: The Potential Use of Algal Growth in Establishing a Postmortem Submersion Interval (PMSI)*

ABSTRACT: While algal community composition has been examined as a qualitative indicator of postmortem submersion interval (PMSI), there have been no quantitative studies on using algal growth rates as PMSI estimators. The present study was undertaken to examine pig decomposition in streams and to develop a more quantitative approach to estimate a PMSI. Pigs and ceramic tiles were completely submerged and regularly sampled for periphyton growth. Five stages of decomposition were identified for the submerged pig carcasses according to physical characteristics. Algal growth rates, measured quantitatively as a function of chlorophyll-a concentration, were greater on pigs compared with tiles; however, microhabitat (pools versus riffles) did not significantly influence algal growth. Additionally, there was a strong correlation between algal growth rate and time on pigs and tile substrates. This strong correlation was observed after significant rain events. Our study documents for the first time a quantitative technique to determine the length of time a corpse has been submerged in water. We suggest that algal growth rates may be a useful quantitative indicator in criminal investigations involving corpses that are completely submerged in stream or riverine habitats.

KEYWORDS: forensic science, forensic botany, postmortem submersion interval

Recently, the potential use of aquatic organisms such as macroinvertebrates (1–5) and algae (6) in the estimation of postmortem submersion interval (PMSI) has received increased attention. Merritt and Wallace (5) noted that the majority of forensic studies dealing with corpses/carrion have concentrated on terrestrial environments compared with aquatic ecosystems. Additionally, those studies pertaining to corpses in aquatic systems focused primarily on terrestrial insects colonizing the corpses as they bloat and rise to the surface (7). With a few possible exceptions (8–11), no true aquatic insects have evolved to feed exclusively on decomposing carrion. Haskell et al. (2) stated that the primary problem in aquatic environments is there are no purely sarcophagous insects to compare with the common terrestrial indicator species such as blow flies (Calliphoridae) and cheese skippers (Piophilidae). While no direct sarcophagous food chain appears to exist between aquatic insects and submerged carrion, there may be a forensically useful link between submerged carrion and the growth of benthic algae on such carrion.

Algae are ubiquitous in aquatic systems, present throughout the year, and easily identified with a light microscope (12). Benthic algae, or periphyton, grow attached to submerged substrates. Nutrients induce changes in algal community structure, including total biomass, productivity, and species richness and diversity (13). Nutrient-release by natural or decomposing substrates may positively affect algal growth. In a study on the initial colonization of periphyton on natural and artificial substrates of the aquatic emergent, *Myriophyllum heterophyllum*, Morin (14) found that while algal community composition was not altered by the difference in substrates, the natural substrate positively affected the total algal biomass. Fairchild et al. (15) noted significantly greater algal growth on phosphorous-diffusing clay flowerpots compared with control pots. The positive correlation between nutrient-releasing substrates and algal growth suggests that the efflux of nutrients from a submerged corpse may influence the growth of a periphytic algal community on the corpse, making algae a potentially valuable forensic indicator organism. Keiper and Casamatta (11) have suggested that forensic investigators should examine the role of aquatic plants more extensively. Although Casamatta and Verb (12) have provided qualitative methods for estimation of a postmortem submersion interval using benthic flora, there is little quantitative evidence for a postmortem submersion interval estimate in freshwater systems.

Algae are commonly used to determine cause of death in cases of potential drowning (11,16–18) and have been used to link suspects to crime scenes (19). In their review, Merritt and Wallace (5) stated that algal species composition and abundance might prove useful in submersion interval estimation. Casamatta and Verb (12) taxonomically examined the role algae plays in the decomposition process of submerged rats. While several algal taxa (*Meridion circulare, Synedra ulna*) were common to both pools and riffles throughout the sampling period and thus provided no usefulness as indicator species, other diatom taxa, such as desmids, were found to be potential indicators of submersion interval. A combination of taxa, including early and late colonizers, might provide important clues as to postmortem submersion interval (12).

The goal of our research was to examine pig decomposition in streams and develop a more quantitative approach to estimate a postmortem submersion interval. The objectives of this study were to: (1) more fully describe submerged stages of decomposition as well as determine the number of degree-days per stage of decomposition, (2) compare algal growth on pigs versus tiles over time,

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and (3) determine if algal growth rates differ spatially between riffle and pool habitats.

Materials and Methods

Study Sites

The study was conducted from November 2000 to April 2001 in two second-order streams (Little Conestoga Creek and Chickies Creek) in Lancaster County, Pennsylvania. Both streams were located within the Lower Susquehanna River Watershed. The Little Conestoga site is located within a semi-forested area in the Boyer Nature Preserve and is immediately downstream of agricultural fields, while the Chickies Creek site is located adjacent to agricultural land. Open canopies permitted direct sunlight throughout the day at each stream site. Using substrate classification of Gordon et al. (20), stream substrates for riffles and pools were similar between stream sites as riffle substrates in each stream consisted of cobble-size (>64 mm) substrate, and pool substrates consisted of a mix of smaller particles.

Physical/Chemical Analysis

In order to calculate degree-days, water temperature for each stream was recorded at continuous 10-min intervals throughout this study using an OnSet® Tidbit temperature probe (Onset Computer Corporation, Bourne, MA). Using stainless steel wire, each probe was attached to a hollow concrete block and submerged for the duration of the periphyton sampling period. Water chemistry measurements were taken on three separate dates during the study for additional stream comparisons. Water samples were collected and returned to the lab where alkalinity and hardness (mg/L as $CaCO_3$) were measured using a Hach® Titration Kit (Hach®, The Celtic Engineering Company, Dublin, Ireland). The pH (standard units) was recorded at each site using a pH meter, and dissolved oxygen (mg/L) was measured once in the middle of the study using a Hydrolab® water chemistry probe (Hydrolab Corporation, Austin, TX).

Periphyton Collection

In order to simplify logistics and minimize attraction from potential scavengers, stillborn pigs were used in this study and obtained from the Penn State University Swine Research Facility located at State College, Pennsylvania. The Pennsylvania Fish & Boat Commission granted permission to conduct this research in streams via scientific research permit #207, Type I.

Pigs and unglazed ceramic tiles (7.62 × 7.62 × 0.635 cm each) were used as substrates for periphyton growth. Six pigs (three in both riffle and pool habitats) and six sets of ten tiles (three in both riffle and pool habitats) were submerged in predetermined high-flow (riffle) and low-flow (pool) microhabitats in each stream.Water velocities ($m \cdot sec^{-1}$) directly upstream of each pig placement site were recorded using a Flowmate® (Marsh/McBirney, Inc., Frederick, MD) to ensure that riffles and pools were significantly different throughout the study and that microhabitat comparisons could be made. Pigs were placed in small trays inside small Havahart® traps (Havahart®, Animals B-Gone, Orrstown, PA) (0.61 × 0.18 × 0.18 m) to facilitate sampling during the latter stages of decomposition in which carcasses took on a soup-like consistency. Each trap was submerged on rebar previously anchored into the streambed (Fig. 1).

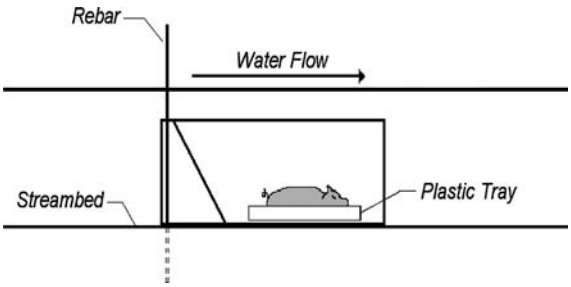

FIG. 1—*Stream experimental design used to maintain pig carcasses submerged during the study period in both streams, Little Conestoga and Chickies Creeks: pig carcass inside Havahart® trap submerged on rebar.*

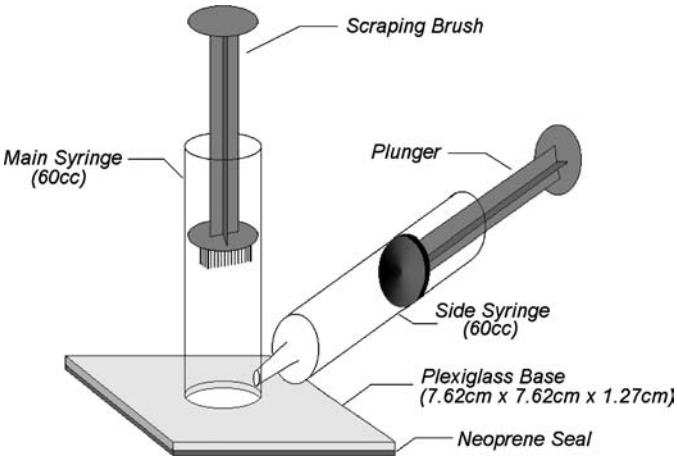

FIG. 2—*Diagram of modified 2-syringe periphyton sampler based on Loeb model (21).*

Pigs were weighed every four days with an electronic field balance in order to quantify weight loss during decomposition. Periphyton was sampled from pigs and tiles every four days from the date of initial submersion throughout a 40-day period ($n = 10$ sample dates) from November 10 through December 20, 2000. A 40-day sampling period for periphyton allowed stabilization of a periphyton community on the substrates. Sample collection was performed every four days for logistical purposes.

A periphyton sampler was assembled to obtain samples from both pig carcasses and unglazed ceramic tiles (21) (Fig. 2). To obtain a sample of periphyton, the sampler was placed firmly against the substrate to form an airtight seal. Distilled water was poured into the main syringe so that the syringe was approximately two-thirds full. The main syringe plunger, refitted with a soft brush, was then inserted into the water-filled main syringe until the brush made contact with the substrate being sampled. Pressed against the substrate, the brush was rotated ten complete rotations to the left and to the right in order to remove any algae attached to the substrate. The brush was then slowly removed from the slurry-filled main syringe and placed directly into a side container. The periphyton slurry in the main syringe was then extracted into the side syringe. In order to collect any remaining loosened periphyton, additional distilled water was poured into the main syringe. The remaining periphyton slurry was extracted into the side syringe. With the side syringe filled with periphyton slurry, the seal between the base of the sampler and substrate was broken. The sampled slurry was deposited into a labeled whirl-pak bag. The brush used to scrape the substrate was rinsed with distilled water into the whirl-pak bag in order to account for periphyton caught in the brush. The

whirl-pak bag was placed on ice in a cooler and returned to the lab for filtering.

Chlorophyll-a Analyses

In the lab, samples were filtered using Whatman® glass microfibre filters (diameter = 47 mm; pore size = 7 μm)(Whatman® International Ltd., UK); the filters were then placed in clean, black film canisters in a freezer until ready for fluorometric chlorophyll-a analysis.

Prior to analysis, the chlorophyll was extracted from the filters via grinding. Each filter was placed into a glass grinding tube using watchmaker forceps. Buffered acetone (90%) was added to the grinding tube and the sample was grinded using a pestle. The resulting slurry was poured into a capped 15 mL centrifuge tube. The pestle and grinding tube were rinsed with the acetone solution and the rinse was added to the centrifuge tube. The centrifuge tube was shaken vigorously and placed horizontally in a refrigerator to steep for 2 to 24 h. Afterward, this slurry was centrifuged at 3000 rpm for 15 min (5°C). Prior to each extraction, the pestle and grinding tube were rinsed with the acetone solution.

Following centrifugation, the supernatant of the each sample was poured into a sample cuvette and the volume was recorded. Acetone solution (90%) was used to zero the fluorometer. The fluorescence of the sample was recorded. Dilutions (range 1:1 to 20:1) were used when necessary and factored into subsequent chlorophyll-a calculations. Samples were acidified with HCl to correct for phaeophytin-a, a degradation product of chlorophyll-a, and fluorescence was measured again.

Statistical Analyses

Mean alkalinity, hardness, and pH values were compared between streams using a 1-way analysis of variance (ANOVA). Mean water flow rates for riffle and pool microhabitats of each stream were compared using a 1-way ANOVA.

Mean initial carcass weight and mean weight loss were compared by microhabitat using a 1-way ANOVA. Linear regressions were used to analyze the correlation between mean carcass weight loss and time and between microhabitats. Stages of decomposition were delineated according to the physical deterioration patterns of the carcasses over time. Mean stage durations (days) were then determined for each microhabitat. Using data collected from the Chickies Creek temperature probe, degree-days were calculated for the Chickies Creek carcasses ($n = 3$ riffle pigs, $n = 2$ pool pigs). Degree-days for each stage of decomposition were calculated by determining daily mean stream temperatures (°C) and totaling all daily mean stream temperatures within each stage for each microhabitat. Negative daily mean stream temperatures were treated as 0 degree-days. Mean degree-days required for completion of decomposition in each microhabitat were compared using a 1-way ANOVA.

Mean algal growth as a function of chlorophyll-a concentration was compared for substrates (pigs versus tiles) and habitats (riffles versus pools) using a 1-way ANOVA and a Fisher's Pairwise Comparison (95% CI). These algal growth comparisons were performed for both 32-day ($n = 8$ sampling dates) and 40-day ($n = 10$ sampling dates) submersion intervals. Linear regressions at 32-day and 40-day submersion intervals were performed to examine spate impact on algal growth.

Results

Water chemistry results showed multiple similarities between the streams (Table 1). There was no significant difference in hardness ($F = 4.70,\ P = 0.10$), alkalinity ($F = 7.09,\ P > 0.05$), or pH ($F = 2.10,\ P > 0.05$) between Little Conestoga Creek and Chickies Creek. Dissolved oxygen was slightly higher in Little Conestoga Creek. Mean water velocities were significantly greater in riffle microhabitats compared with pool microhabitats in Little Conestoga Creek ($F = 23.17,\ P < 0.01$) and Chickies Creek ($F = 28.4,\ P < 0.01$). We observed no significant difference in riffle ($F = 0.76,\ P > 0.05$) or pool velocities ($F = 4.50,\ P < 0.05$) between sites.

We characterized five stages of decomposition in stream habitats (Table 2). There was no significant difference in mean initial pig weights in riffles compared with pools in either Little Conestoga Creek ($F = 0.01,\ P > 0.05$) or Chickies Creek ($F = 0.07,\ P > 0.05$). As decomposition progressed, there was no significant difference in mean weight loss in riffles compared with pools ($F = 2.88,\ P > 0.05$). Pig weight loss in riffles ($r^2 = 0.80$) and pools ($r^2 = 0.61$) was positively correlated with time since initial submersion (Fig. 3). Additionally, there was a positive correlation ($r^2 = 0.81$) of mean weight loss between riffles and pools (Fig. 4). Pigs submerged in pool microhabitats required a greater total number of degree-days for completion of decomposition compared with pigs submerged in riffles (Table 2).

We observed significantly greater algal growth in terms of chlorophyll-a production on pig carcasses compared with tile substrates following both 32-day ($F = 5.65,\ P < 0.005$) and 40-day ($F = 8.00,\ P < 0.001$) submersion intervals (Fig. 5). We also note, in Fig. 5, that microhabitat (riffle versus pool) did not significantly affect algal growth rates on either substrate (pigs versus tiles). There was a positive correlation between chlorophyll-a concentration and time following a 32-day submersion period (pigs: riffle $r^2 = 0.79$, pool $r^2 = 0.78$; tiles: riffle $r^2 = 0.58$, pool $r^2 = 0.59$). After a 40-day period, we observed a similar positive correlation between chlorophyll-a concentration and time. However, this relationship was not as strong on either substrate (pigs: riffle $r^2 = 0.37$, pool

TABLE 1—*Water chemistry analysis of Little Conestoga Creek and Chickies Creek, PA. Values presented are mean values with standard errors (SE). Dissolved oxygen measurements taken one time are presented as single measurements, November–April, 2000.*

	Little Conestoga Creek		Chickies Creek	
Parameter	Mean	(SE)	Mean	(SE)
Hardness ($mg \cdot L^{-1}$ as $CaCO_3$)	297.0	(10.3)	262.3	(12.3)
Alkalinity ($mg \cdot L^{-1}$ as $CaCO_3$)	205.0	(6.5)	172.3	(10.4)
PH (standard units)	7.15	(0.15)	6.53	(0.40)
DO ($mg \cdot L^{-1}$)	6.80		5.90	
	Riffle	Pool	Riffle	Pool
Flow rate ($m \cdot sec^{-1}$)	0.33 (0.03)	0.05 (0.01)	0.40 (0.04)	0.01 (0.00)

TABLE 2—*Observed stages of decomposition with corresponding physical descriptions from submerged pigs in the Little Conestoga and Chickies Creek.*

Stage of Decomposition	Physical Description of Carcass
(1) Submerged fresh	Fresh; no outward signs of decomposition; still sunken; stage ends when body floats to surface
(2) Early floating	Bloated; floating on surface of water; cage indentations on carcass as it presses against the top of the cage; algal growth evident
(3) Early floating decay	Minor decay becoming apparent; sloughing of flesh; loss of muscle mass or "thinning" of hind limbs; eyes and soft tissues becoming disarticulated; head and legs remains intact; identity of carcass as being that of a pig still evident
(4) Advanced floating decay	Major deterioration visible; ribs and skull exposed; breaks in and loss of bones, including skull; leg bones gone; carcass identity becoming indistinguishable as a result of major appendage and skull loss; stage ends as remains sink
(5) Sunken remains	Remains sunken to bottom of cage; any skin takes on a "soup-like" consistency; stage ended arbitrarily with mostly small pieces of bones remaining

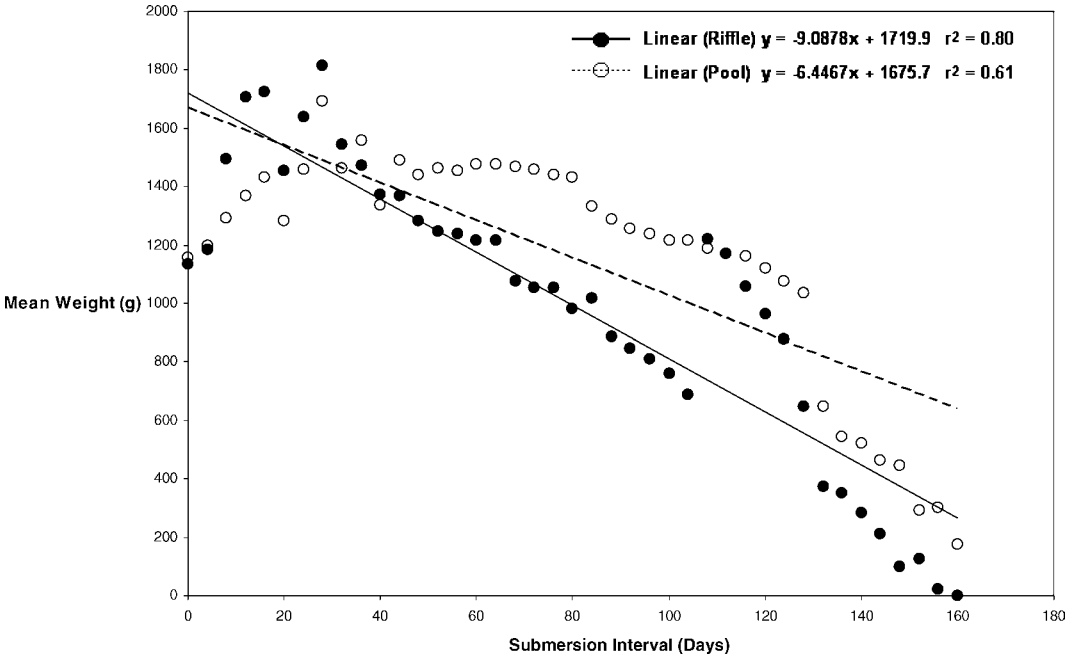

FIG. 3—*Mean weight loss of carcasses in riffle and pool microhabitats over time.*

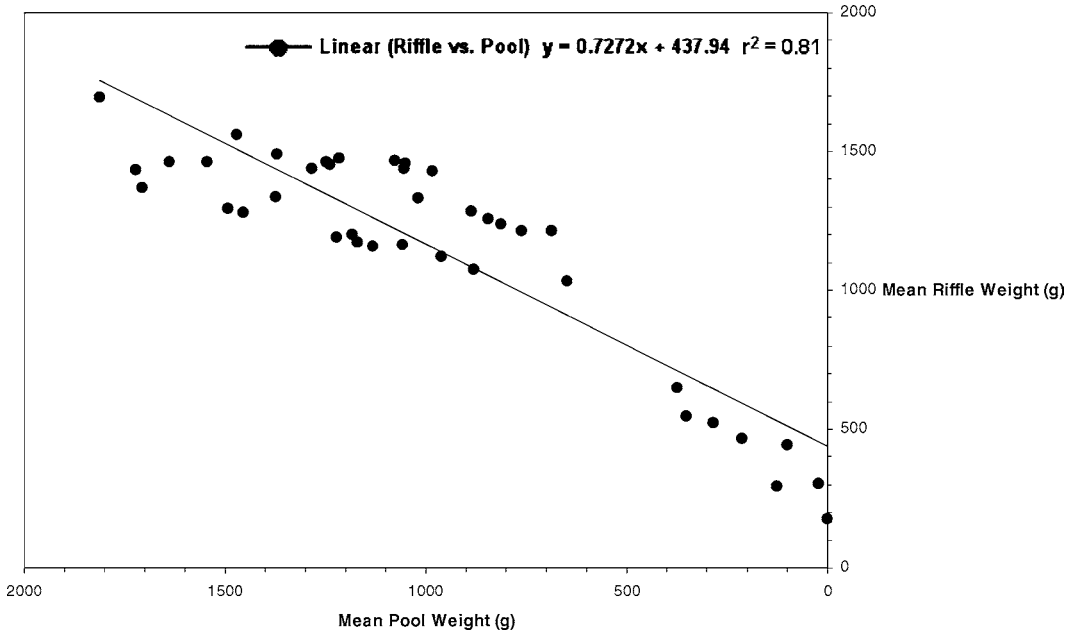

FIG. 4—*Linear regression analysis comparing mean carcass weight in riffles versus pools.*

TABLE 3—*Mean temperature and total degree-days per stage of decomposition in riffle and pool habitats of Chickies Creek, PA. Standard errors of the mean are in ( ), (*n = *3 riffle;* n = *2 pool habitats).*

	Temperature (°C)				Total Degree-Days	
	Riffle		Pool			
Stage of Decomposition	Mean	(SE)	Mean	(SE)	Riffle	Pool
(1) Submerged fresh	9.6	(0.60)	6.3	(0.57)	76.8	151.2
(2) Early floating	3.9	(0.25)	2.0	(0.18)	118.1	88.6
(3) Early floating decay	1.6	(0.15)	3.5	(0.25)	70.0	152.3
(4) Advanced floating decay	4.1	(0.33)	6.7	(0.25)	64.9	242.0
(5) Sunken remains	4.2	(0.52)	10.7	(1.05)	34.0	139.2
				Total	363.8	773.3

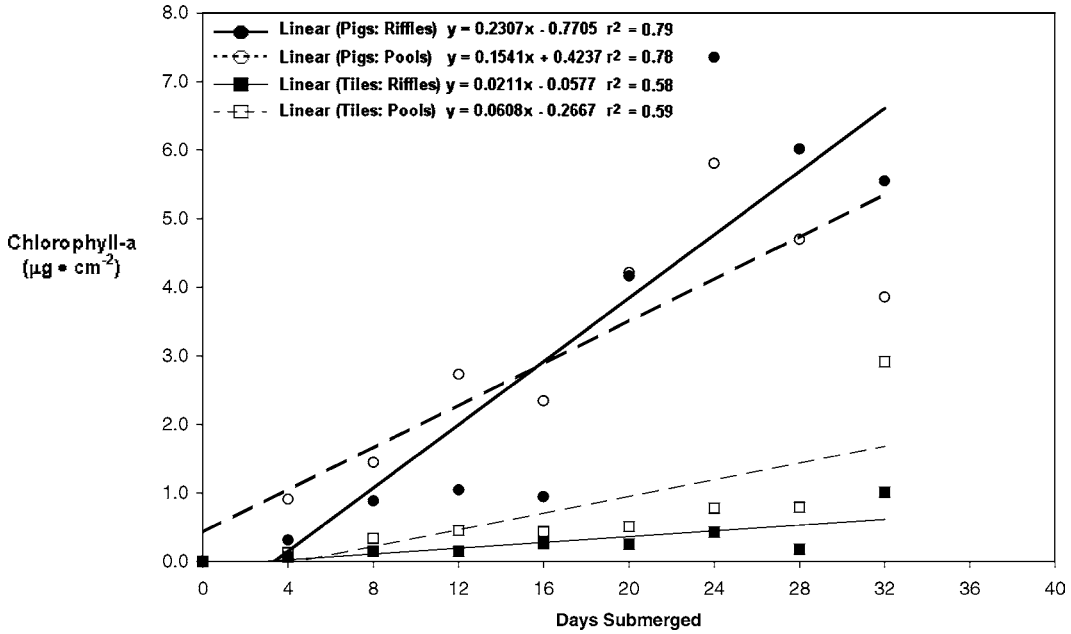

FIG. 5—*Linear regression analysis of algal growth as a function of chlorophyll-a concentration on pig carcasses versus tiles through a 32-day submersion interval in (eight sampling dates).*

$r^2 = 0.36$; tiles: riffle $r^2 = 0.43$, pool $r^2 = 0.22$) due to the unexpected rain events that occurred on days 33–34 and 36–38 (Fig. 6).

Discussion

In the present study, we characterized five stages of decomposition for the remaining pig carcasses according to physical characteristics. Comparatively, previous investigators have identified six stages of decomposition for corpses in aquatic systems (7,22). While these earlier studies allowed submerged carrion to float to the surface, in this study, Havahart® traps prevented the pigs from reaching the surface, prohibiting colonization by terrestrial species of insects. We found no discernable difference between the "floating decay" and "bloated deterioration" stages as described by Payne and King (22). Perhaps the absence of terrestrial insects during the decomposition process resulted in fewer stages.

Upon submersion, carcasses in both habitats gained weight for approximately 30 days as a result of becoming saturated. Following this initial increase, mean weight decreased in a similar manner between each microhabitat for the duration of the study. The first two stages of decomposition correspond to those first described by Payne and King (22) (Table 2). Each carcass began in a submerged fresh stage where there were no outward signs of decomposition on the body, and the carcass was below the water surface. The early floating stage commenced as the carcass floated to the top of the Havahart® trap, causing visible wire indentations on the head and torso. Heavy algal growth was evident on the carcass during this stage. At this point in the decomposition process, we noted differences between stages characterized in our study and those identified in previous work (22). We characterized only two intermediate stages (early floating decay and advanced floating decay) for a decomposing carcass as it floated at the top of the cage, whereas Payne and King (22) characterized three stages (floating decay, bloated deterioration, and floating remains) for a carcass floating on the surface of the water. While pig carcasses were completely submerged throughout the duration of this study, the number and description of each stage closely resembled those observed by Davis and Goff (23) in their study in anchialine or brackish ponds. Descriptions of intermediate stages in earlier studies were based solely on decay induced by terrestrial insects. Payne and King (22) described the floating decay stage by the intense maggot feeding activity that resulted in the creation of many openings in the exposed skin. Since terrestrial oviposition was prevented in our study, descriptions of these middle stages were based entirely on physical deterioration of the carcass. In our study, the early floating decay stage, in which the carcass could still be identified as that of a pig, was distinguished by the appearance of minor decay, including darkening and sloughing of flesh, disarticulation of eyes and soft tissues, and thinning or

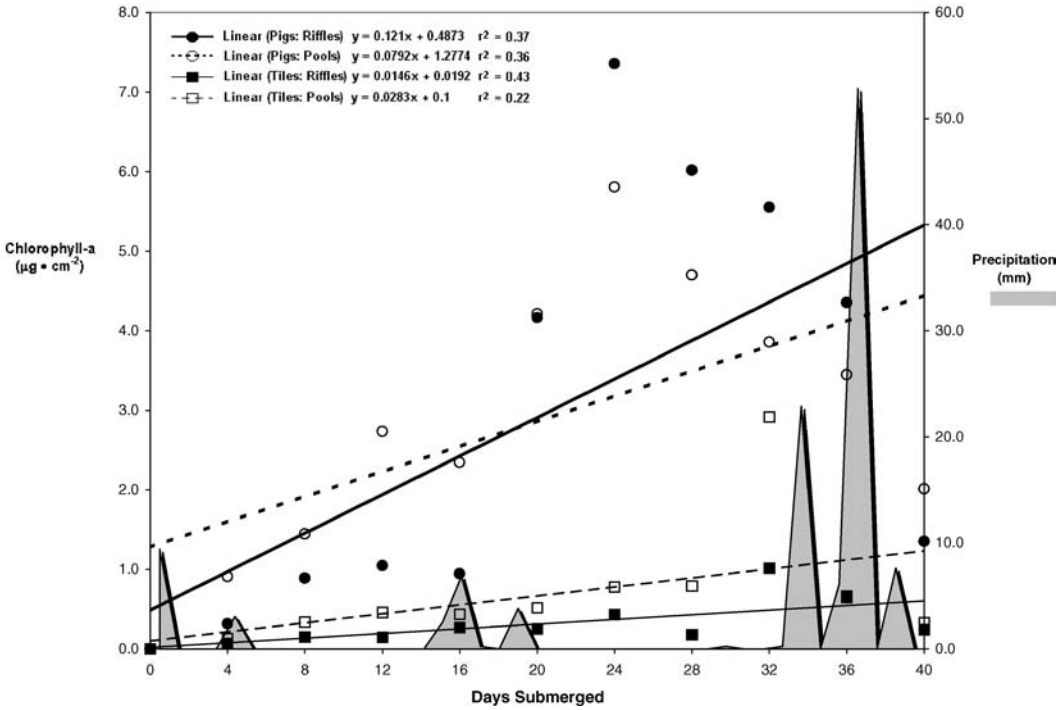

FIG. 6—*Linear regression analysis of algal growth as a function of chlorophyll-a concentration on pig carcasses versus tiles through a 40-day submersion interval. (Ten sampling dates; right* y*-axis depicts precipitation amounts illustrating rain events (specifically significant events on days 33–34 and 36–38 of study).*

loss of muscle mass, especially in the legs. The advanced floating decay stage was characterized by major deterioration, including the appearance and eventual disarticulation of the skull, ribs, and limb bones. This substantial bone loss resulted in the lack of a recognizable body shape. This stage ended with the sinking of the remains. The final stage of the decompositional process in our study is consistent with the final stage described in earlier studies. The sunken remains stage consisted mostly of bones covered by very little flesh of a soup-like consistency. We arbitrarily ended this stage when only small pieces of bone remained.

Investigators may be able to estimate a submersion interval of a submerged carcass by knowing several pieces of information, e.g., including the physical decompositional stage of a carcass, number of degree-days required to reach each stage, and the microhabitat in which the carcass was found. Once stages of decomposition were delineated in this study, we determined the mean number of degree-days required per stage for submerged carcasses in each microhabitat in Chickies Creek. We found that complete carcass decomposition in riffles was faster and required significantly fewer degree-days than in pools. The accelerated decomposition in riffles may be attributed to water velocities, which were significantly faster in riffles. The increased turbulence in riffle microhabitats may have led to increased sloughing of flesh, prompting faster disarticulation of muscle and bones (24).

Algal growth rate as a function of mean chlorophyll-a concentration was not significantly different between riffles and pools in this study. Keiper and Casamatta (11) suggested six areas of study to enhance the applicability that algal growth comparisons should be made between artificial substates and mammalian carcasses. The areas they suggest further study on to enhance medicolegal investigations utilizing basic benthological information include: (1) quantitative documentation of the colonization of replicated mammalian carcasses in situ; (2) comparison of algal colonization on artifical substrates such as tiles and mammalian carcasses; (3) examination of seasonal effects on colonization; (4) determination if large scavengers alter decomposition or affect coloniation; (5) experimental effects of severe disturbance such as rain events or spates on attached biota of mammalian carcasses; and (6) examination of how clothing may alter colonization by benthic organisms. We have addressed several of these recommendations and shown that algal growth rate on pigs was significantly greater compared with that on tiles. This increased growth rate on pigs might be attributed to spatial heterogeneity on the pig carcasses. Keiper and Casamatta (11) noted that spatially heterogeneous substrates provide more attachment sites and protection from stream turbulence than comparatively simple ones such as tiles. Another potentially significant influence on algal growth rate is the release of nutrients from the carcasses during the decomposition process. Fairchild et al. (15) found that, over time, increased periphytic algal growth was observed on the nutrient-releasing pots compared with control pots. As corpses decompose in aquatic systems, cells lyse and release nutrients into the surrounding water. Earlier work by Schultenover and Wallace (unpublished studies cited in Merritt and Wallace (5)) hypothesized that human remains in water may provide substrate upon which primary producers such as algae can colonize and grow. The submerged body may act as a nutrient source for colonizing algae, whereas a submerged artificial substrate such as a tile or brick does not release nutrients.

Merritt and Wallace (5) indicated that algal growth on an aquatic substrate such as a pig or human corpse may occur in a successional manner, and therefore early algal colonizers pave the way for late-arriving species. This hypothesis was supported by empirical work on algal community succession correlated with stages of decomposition (12). Casamatta and Verb (12) qualitatively identified early and late algal colonizers on submerged rat carcasses and demonstrated that the presence or absence of these indicator algal species may lead to an estimation of a postmortem submersion interval. Graham and Wilcox (25) also state that after initial colonization by diatoms on submerged substrates and through early development, a

complex mat having maximum biomass accumulates. Although we did not qualitatively characterize the periphyton growth on pigs, we did observe a flattened initial layer and over the sampling period a more complex and dendritic or tree-like algal mat appeared.

To date, studies quantitatively measuring algal growth on corpses are lacking. However, in our study, algal growth rates on the pig carcasses measured as a function of chlorophyll-a concentration were strongly correlated with time since submersion. This correlation was stronger for the submersion interval preceding the rain events compared with the time following these spates. Two significant rain events occurred approximately at day 33–34 (rainfall amount $\approx$ 2.5 cm) and days 36–38 (rainfall amount $\approx$ 6.3 cm) of the study, producing severe flooding. Chlolorphyll-a measurements for the dates preceding these events decreased. This does not indicate decreased algal growth post flooding; rather, the increased turbulence caused by the flood event most likely resulted in algae sloughing from the carcasses. Rain events or spates may disrupt the algal community, thus decreasing the population in quality and quantity through shearing effects. In their study, Power and Stewart (26) noted that approximately two thirds of the algal assemblages in an Oklahoma stream were lost during a spate. Graham and Wilcox (25) stated that high shear stress, a result of stream turbulence, may lead to sloughing of larger more vulnerable algal communities while smaller intrinsically resistant algae, along with those species occurring in protected areas of a stream, may survive such scouring. Because scouring can retard or reset the colonization clock by reducing the algal community on a substrate, both in density and diversity, investigators interested in estimating a PMSI using algal quantification must account for recent rain events that could initiate such a reduction. The severity of these rain events should also be measured in terms of impact on existing algal communities.

Although only a paucity of evidence exists on a quantitative method to estimate a postmortem submersion interval in aquatic systems, we feel that reliable PMSI estimates can be made for bodies submerged in lotic and lentic (e.g., ponds and lakes) aquatic systems based on several variables. Establishment of the stage of decomposition for a submerged body, in conjunction with the calculation of relevant degree-day information, may allow investigators to better estimate PMSI. Degree of algal growth on the submerged body would further serve to delineate PMSI. However, as algal growth rates were significantly greater on the natural mammalian substrates compared with rates on artificial tiles, it appears unlikely that artificial substrates adequately approximate a corpse. Therefore, previous studies involving algal growth on artificial substrates may not be applicable to PMSI determination for submerged corpses.

Acknowledgments

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