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Use of Aquatic Insects in Determining Submersion Interval

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ABSTRACT: Although its potential is great, the use of aquatic insects in determining submersion intervals at death-scene investigations has not been exploited in the past. Aquatic environments have no known true specific indicator species, as do terrestrial habitats. However, aquatic environmental studies show that organisms may colonize a substrate dependent on factors such as size, position, exposure to current, water temperature, current speed, water depth, the presence of algal communities, or detritus. Certain aquatic insects such as the chironomid midges (Diptera, Chironomidae), and the caddisflies (Trichoptera), are capable of colonizing immersed bodies; and with the known biology of a specific species of insect for a certain geographic area, time intervals of submersion can be established.

KEYWORDS: pathology and biology, entomology, insects, postmortem interval, decomposition, carrion insects

The use of terrestrial insects in determining the amount of time a corpse has been exposed to the environment and the dynamics of the established insect populations have been well documented [*1-7*]. Many corpses, however, are found in aquatic environments which prevent oviposition and subsequent development of terrestrial sarcophagous insect larvae. Payne and King [*8*] studied the colonization by blowflies onto immersed pig carrion in South Carolina, and in 1982, Meek[3] conducted a similar study in Louisiana. Simpson [*9*] remarks on the appearance of blowflies on emersed humans. All of these studies concentrated on blowflies and a few other terrestrial species that colonize the putrid corpse after it floats to the surface. Smith [*10*] notes that little work has been done on the possibility of using aquatic insects found on bodies to determine the length of time the body has been in the water. We know of no published studies defining the use of aquatic insects to determine the length of time the body has been in the water.

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[3]Meek, L., unpublished data, Louisiana Pig Immersion Study, 1982; personal communication, Nov. 1987.

The postmortem interval (duration of time since death) for a putrid body colonized by terrestrial sarcophagus insects can be estimated if, and only if, variables caused by differences in species life cycle and microenvironment are considered [*1–7*]. Ordinarily, careful observation and collection of insects at the scene can allow for scientific estimation of these variables. The aquatic environment is a new frontier for forensic entomology. In the following paragraphs we will attempt to define some of the measurable variables relevant to species and microenvironment that allow interpretation of aquatic insect colonization to estimate the submersion interval. The primary problem in aquatic environments is that there are no purely sarcophagous aquatic insects to compare with the common terrestrial indicator species such as blow flies (Calliphoridae) (Fig 1*a*), carrion beetles (Silphidae) (Fig. 1*b*), or the cheese skipper (Piophilidae, *Piophilia casei L.*). Facultative sarcophagy, however, has been reported for some aquatic species [*11*]. Aquatic insects feed primarily on algae, decaying plant matter, or other insects. They do not commonly have access to submerged carrion of large animals; therefore, specialized sarcophagous feeding habits have not evolved in the aquatic insect species.

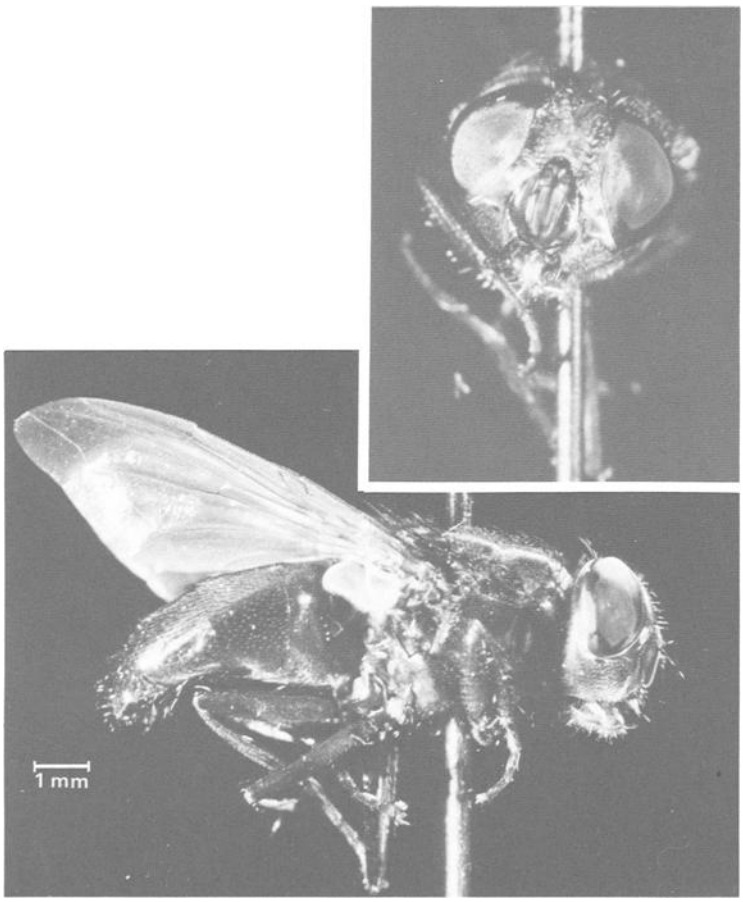

FIG. 1*a*—*Calliphoridae (blow fly).*

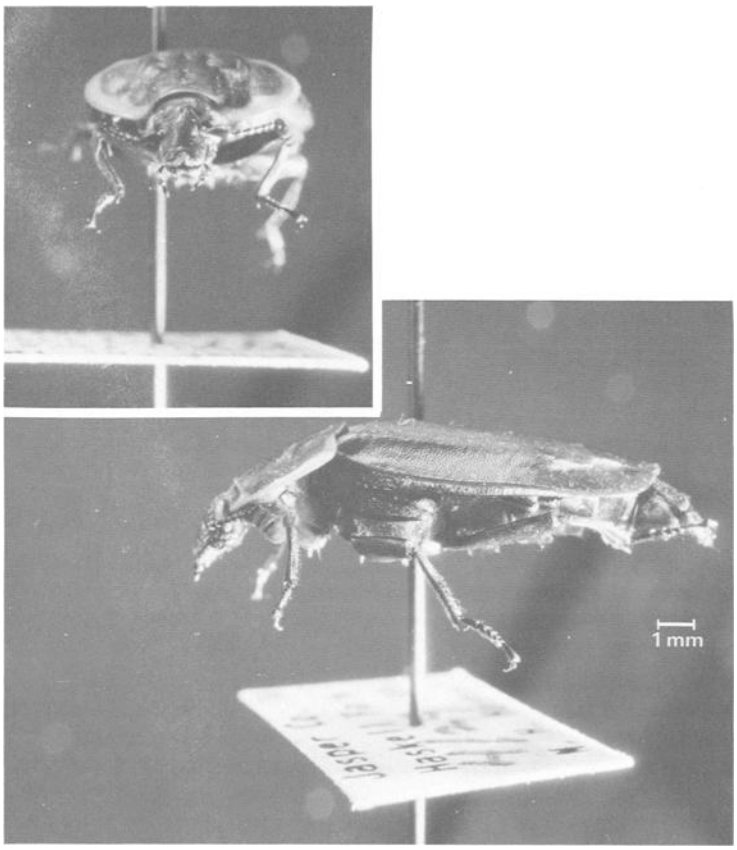

FIG. 1*b*—*Silphidae (carrion beetle).*

In spite of the lack of specific indicator species in the aquatic environment, there is tremendous potential for determining the submersion interval for a human body. Some factors that may help determine submersion interval are progression in development, on the corpse, of algae and aquatic insect "communities;" deposition of silt, presence of specific life stages of aquatic insects, presence of specific structures built by aquatic insects, and the presence of species known to inhabit certain microhabitats. The majority of these factors, however, will involve some speculation. The development of an aquatic insect community on an introduced substrate, such as a corpse, is highly dependent on available colonizers, location of introduced substrate, geographic location, seasonality, temperature, and current speed.

Fundamentals of Colonization by Aquatic Insects

Colonization of aquatic insects onto a submerged body is a complex subject. Traditionally, entomologic studies of insect colonization have focused on repopulation of the habitat after some disturbance—drought, flash floods, pesticide applications, or chemical spills. Other studies have focused on the initial colonization of new habitats such as aqueducts or man-made lakes. Of more immediate application to aquatic forensic entomology is the work done with artificial substrates used as sampling devices to obtain representative assemblages

of aquatic insects for insect community studies in water-pollution surveys [*12*]. The theory is that a new substrate will be colonized by chance encounters of organisms with the substrate; if it is suitable, the organisms will stay.

Encounter with the substrate, or corpse, is influenced by current speed, numbers of individual organisms present at varying water depths (water column), and the relative position of the substrate within that water column [*12*]. A recent study [*13*] shows significant variation in the rate of colonization due to seasonal effects of current speed, water temperature, water depth, and so forth. Even in still water, aquatic insects will colonize a substrate suspended in the water column [*14*]. For some organisms, drift in the water column may be an active part of searching out food [*15*]; for other organisms drift may be caused by predation avoidance [*16*], disruption of the substrate [*17*], changes in flow [*18*], insecticides [*19*], or part of a diel (day and night) cycle [*20,21*]. Studies of drift at various times will identify which organisms are most likely to be available for colonization.

Encounters of organisms with substrates tend to be random processes. Some aquatic invertebrates, such as crayfish, are known to use chemical cues to locate food sources. Little is known about the sensory capabilities of aquatic insects. However, there is some evidence [*22*] that chemical cues are not used by these insects to locate their food sources. Motyka et al. [*22*] speculate that aquatic insects, which evolved from terrestrial insects, have not evolved the necessary chemoreceptors for use in the aquatic environment.

Once an organism has reached a substrate, characteristics of that substrate will determine whether or not the organism remains. Some organisms choose substrates having appropriate food resources. For instance, leaf-shredding caddisflies (Trichoptera) tend to select leaves which are colonized by fungi [*23*]. More often, substrate is selected by physical characteristics such as composition, size, exposure to current, or position [*12,24-28*]. The presence of organic detritus, or an algal community, may be important for some species [*26,27,29*], but the distribution of detritus itself is a function of environmental parameters such as current speed.

Despite the apparent randomness of colonization, it tends to be an orderly process [*30*]; with solid research data, mathematical models of immigration can be produced [*31,32*], and regression analysis may be possible. However, use of aquatic insect or algal community data for accurately determining submersion interval will depend on local studies of colonization of bodies under differing seasonal conditions. Without such data, only generalizations can be made. Tevesz [*30*] characterizes early colonization communities as being composed of small organisms with high dispersal powers and broad environmental tolerances; such communities will usually be dominated by a relatively few species. Care should be exercised in using this generalization, however, since these are also the characteristics of polluted water communities.

Aquatic Insect Colonizers

One aquatic insect group, in particular, is characteristic of the early colonizers which might be expected to be found on bodies. The midges (Diptera: Chironomidae) are extremely common in most freshwater situations. An adult midge is shown in Fig. 2, with a generalized life cycle of a midge depicted in Fig. 3. These small, worm-like larvae (often bright red) display all the characteristics of early colonizers described by Tevesz [*30*]. They have been associated with several bodies in Indiana and are doubtless common elsewhere. While the bright red species of Chironomidae are easily noticed, other species of Chironomidae are very difficult to see, particularly because of their small size (<2 cm), or color (pale yellow, transparent, pale green, light brown, and so forth). The diversity of size, color, and other characteristics of common species of Chironomidae is shown in Table 1. Figure 4 shows representative head capsules of Chironomidae taxa groups. Accurate identification of

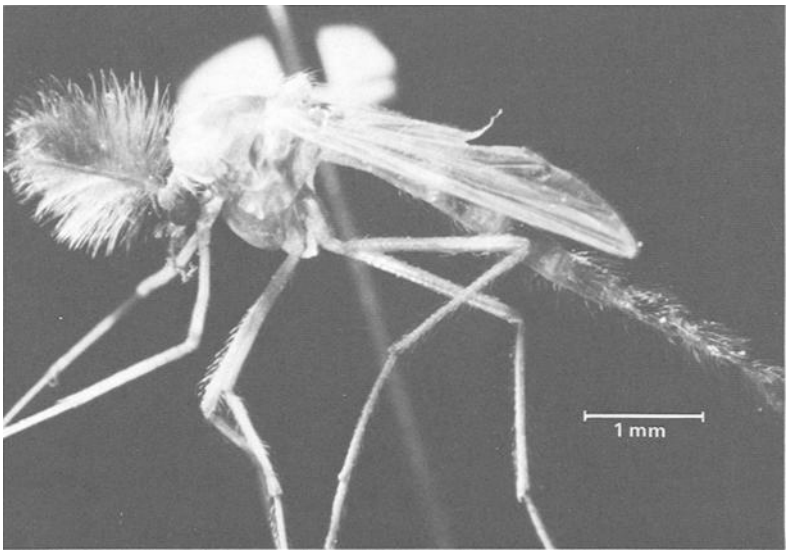

FIG. 2—*Adult chironomid: pinned collection specimen.*

chironomid larvae may provide important clues to the submersion interval, but species identifications are difficult and should only be attempted by a specialist.

Aquatic insects, particularly net-spinning caddisflies and flies such as chironomids, often build structures of silk on the submerged substrate. Aquatic structure building is similar to terrestrial web-spinning observed in other arthropods. Usually the aquatic structures are living tubes or catchnets for filtering small food particles from the water. The entomological literature contains anecdotal references to the length of time required to build such structures; for instance, Cavanaugh and Tilden [*34*] reported that it takes 3 h for one species of midge to build its silk case. Although most structures no doubt are built in such short periods of time, there may still be potential value in close examination of these structures. For instance, if a midge larva molts, its old exoskeleton (called a cast skin) may remain attached to its silk structure or case. If life history data are available for that species, it may be possible to determine, for example, that this particular larva had colonized that corpse for a period of several days to weeks.

Case-building caddisflies may also provide clues since they build portable cases from local available materials. The composition of the case may help in determining transfer or movement of a corpse from one aquatic habitat to another. These data must be interpreted with extreme care, however, since these insects may have moved from the location where the case was built independent of the movement of the corpse.

Sometimes the association of specific life stages of an insect with a corpse may be helpful. Many species of insects emerge as adults only during fairly well-defined periods, as exemplified by certain mayflies (Ephemeroptera) (Fig. 5). If eggs or cast skins are found on the corpse and the period of flight is known for that species, it may be possible to determine the length of time the body has been submerged.

In some cases, the ecological or behavioral traits of the organisms may provide clues. Finding eggs on the exposed surface of a body, when it is known that this species lays its eggs underwater, indicates that the body was once submerged and has since floated to the surface. Likewise, the discovery of bottom-dwelling organisms on a floating body not in contact

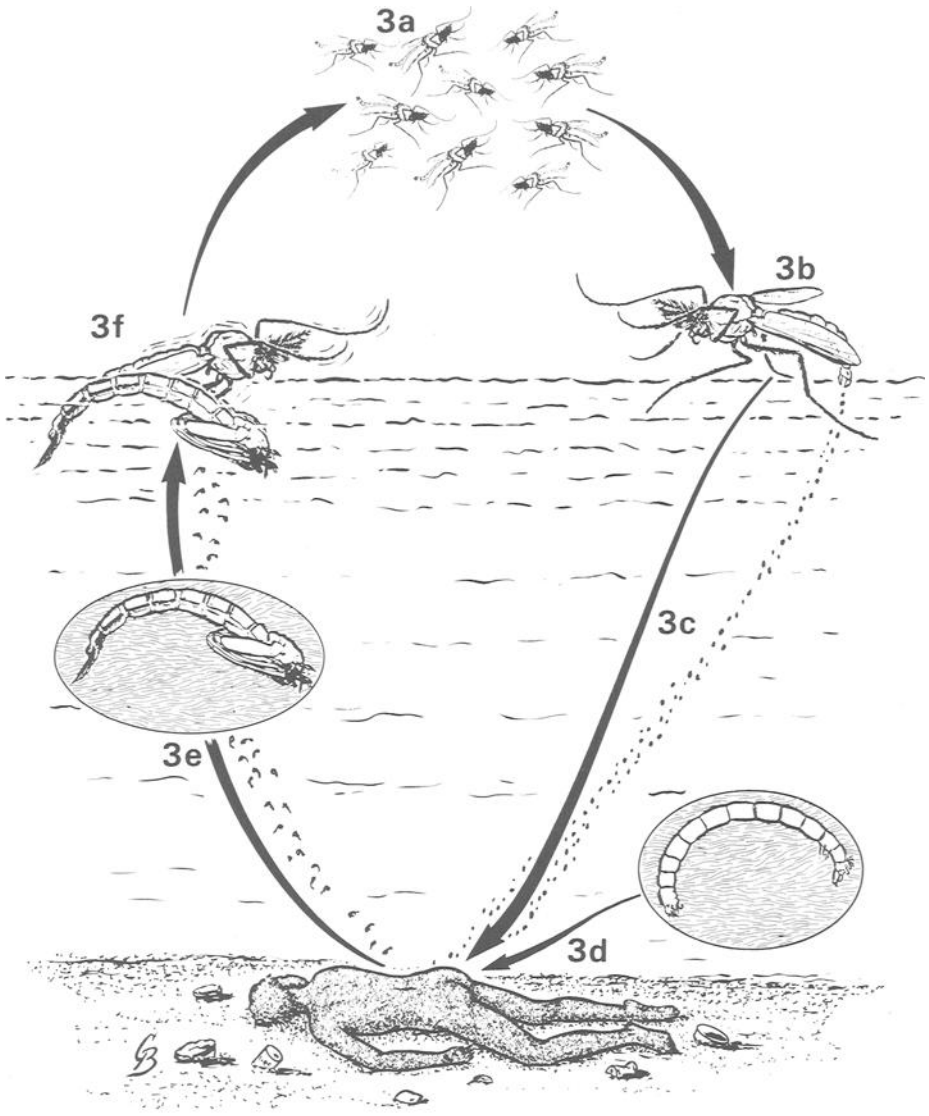

FIG. 3—(a) *Swarming adult chironomids; mating occurs in the swarm. (b) Female ovipositing; most females oviposit on the water surface.* (c) *Eggs settling: eggs settle to the bottom to hatch.* (d) *Larval development; most larvae live on or burrow into the substrate. Feeding takes place during the larval stage.* (e) *Pupal movement to the surface; after developing on or in the substrate, the pupae swim to the surface to emerge.* (f) *Adult emergence; the adult emerges from the pupal skin at the water surface.*

with the bottom may also indicate past submergence depending on the type of insect; however, since most bottom-dwelling insects drift periodically, they may colonize structures in the water not in contact with the bottom. If an insect not known to drift is found on a floating body, the submersion interval could be estimated from stream depth data, weather reports, and so forth.

TABLE 1—*General characteristics of four common groups of Chironomidae.*

Subfamily	Head Capsule	Antennae	Labial Plate	Ligula	Paralabial Plates	Color	Habitat	General Habits	Number of North American Species[a]
Tanypodinae	elongated	retractile	indistinct	present	comb-like or absent	pale yellow	lakes, streams	free-living or predaceous	140
Orthocladiinae	rounded	sessile	triangular	absent	small or absent	pale yellow	mostly streams	case building	400
Chironomini	rounded	sessile	triangular	absent	large, striated	often red	lakes, streams	burrowing	205
Tanytarsini	rounded	on tubercles	triangular	absent	large, striated	pale yellow	mostly streams	case building	110

[a]Number of North American species from Coffman [*33*].

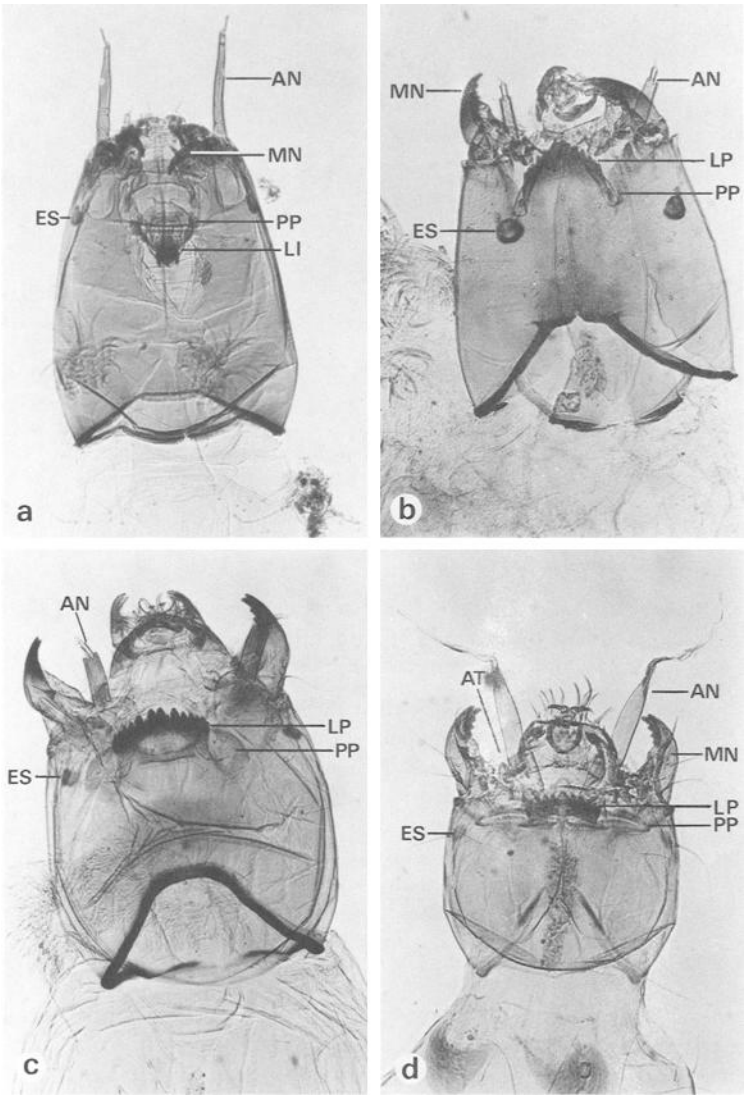

FIG. 4—*Head capsules of four representative chironomid larvae. AN = antenna, AT = antennal tubercle, ES = eyespot, LI = ligula, LP = labial plate, MN = mandible, PP = paralabial plate.* (a) *tanypodinae;* (b) *orthocladiinae;* (c) *chironomini;* (d) *tanytarsini.*

Collection Methods

The proper method for the collection and preservation of aquatic insects is essential for accurate identification of the organism. Several standard techniques are available for use in handling these soft-bodied insects when a death investigation site is being examined.

Flying adult insects which are in close proximity to the body should be collected with an aerial net. The contents can then be funneled into a vial containing 75 to 80% ethanol.

Eggs, larvae, pupae, and adults can be picked off the corpse by using forceps, fingers, or a small scraping tool, as long as extreme care is used to avoid creating any additional postmor-

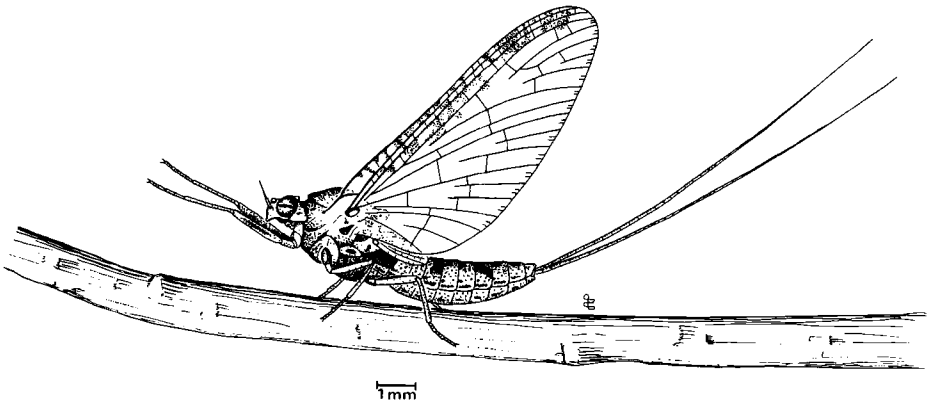

FIG. 5—Callibaetis sp., *Baetidae; Ephemeroptera (mayfly). This genera is a common pond dweller and is also found in backwaters of slower rivers and streams.*

tem wounds. Often, chironomid larvae are found burrowed under the slime and algae which coats the skin or clothing, and they will not be seen if this covering is not scraped off. Once the stages are collected, they should be preserved in one of the solutions listed.

1. 75 to 80% ethyl alcohol: eggs, larvae, pupae, and adults
2. Hood's solution: all stages

ethyl alcohol 75%	95 mL
glycerine	5 mL

3. Kahle's solution: all stages

ethyl alcohol 95%	30 mL
formaldehyde	12 mL
glacial acetic acid	4 mL
water	60 mL

Soft-bodied stages of insects should never be preserved by air-drying or by formalin fixation because of extreme distortion of the morphological characteristics of the insects.

Additional information on techniques of collecting and preserving the aquatic insects can be found in McCafferty [*35*], Borror et al. [*36*], Peterson [*37*], Simpson and Bode [*38*], and Furman and Catts [*39*].

Acknowledgments

Figure 3: George F. Buckley, illustrator, Department of Pathology, Indiana University School of Medicine.

Figure 5: Arwin V. Provonsha, illustrator, Department of Entomology, Purdue, University.

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