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Author(s): W. E. Snow
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point (a physiological expression of the water content of the tissues at death).

The species used in the experiments are discussed with respect to their reactions to desiccation and their habitats.

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STRATIFICATION OF ARTHROPODS IN A WET STUMP CAVITY

W. E. Snow

Division of Health and Safety, Tennessee Valley Authority, Wilson Dam, Alabama

Few workers in the United States have investigated the arthropod populations inhabiting wet stump holes. Generally, only restricted groups or individuals have been reported from such cavities. In 1861, Benjamin Walsh observed the larvae of an helodid beetle, *Prionocyphon discoideus* Say, in a stump hole near Rock Island, Illinois, and communicated his detailed findings to Osten Sacken (1861). A puparium of the syrphid *Criorhina pictipes* was reported from a stump hole in Virginia by Greene (1923). He also found species of several other genera in moist tree cavities. Jenkins and Carpenter (1946) have compiled records of tree hole mosquitoes some of which also breed in wet stump holes. While studying the breeding sites of tabanids in the Yazoo-Mississippi Delta, Lewis and Jones (1955) found larvae of *Leucotabanus annulatus* Say to occur commonly in willow stumps, particularly those surrounded by coppice. During the past two years random observations have been made on arthropods found in a wet stump hole near Town Creek, Alabama. It is the purpose of this paper to identify these individuals and to consider their position within the microhabitat.

Habitat Conditions

The tree stump was situated among smartweed and buttonbush at the outer margin of a limesink called Meadow Pond about a mile north of Town Creek, Alabama (Fig. 1). The portion of the sink about the stump was intermittently flooded to a depth of several inches, but the ground water table did not affect the water level within the stump. The original tree, a sweet gum (*Liquidambar styraciflua* L.), was cut down several years ago leaving a stump approximately 30 in. high and 26 in. in diameter with a hole in the middle about 16 in. across at the top. In the interior of the stump some heartwood persisted on the east side, but only pulpy sapwood remained on the west side in the dry wall portion. Coffee-colored water that was retained in the base during most of the year had a depth of over one foot in the spring but was considerably lower in the fall. With the exception of certain mosquitoes, the larval forms of aquatic Diptera present were able to pass the fall dry period in moist, woody debris at the base of the cavity.

Portions of the interior of the stump roughly including the north wall and adjacent water surface were reached by direct sunlight during midday hours in summer. Midday temperatures (° F) taken during visits in 1956 were as follows:

	April 25	*May 19*	*June 8*	*June 30*	*August 7*
Dry Wall	69	84	78-80	83	93-94
Water	57-59	71	75	83-85	83-84

One nighttime temperature reading on July 3, 1956, at 0230 hours suggests a slight dropoff overnight with wall temperature at 79° F and water temperature at 75° F. Air temperatures recorded

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FIG. 1. Sweet gum stump at edge of Meadow Pond, Town Creek, Alabama, used in observations on stratification of arthropod populations, August 10, 1956.

at Muscle Shoals, Alabama, from October 25, 1955, through March 1956 show the number of days with temperatures below freezing as follows: October —1; November —12; December —15; January —20; February —5; and March —8. Minimum temperature of 14° F was reached on December 16, 1955.

PROCEDURE

As a rule samples of wood and stump hole water were returned to the laboratory for rearing of immature insects. Pupae and puparia were removed for individual rearing in order to associate cases and exuviae with the respective imagoes. Isolation of puparia was also useful in detecting hymenopterous parasites of syrphids.

Temperature readings were made from shaded areas on the wall, at the water surface, and several inches below the water surface. Because several local curiosity seekers were roused by visits of the investigator to explore the stump and environs, it was deemed advisable to omit the use of continuous recording devices for climatic measurements. During the last two months of the investigation much of the stump was torn away at the bottom allegedly by such individuals, but the water-retaining capacity of the stump hole was unimpaired.

Wood samples were taken in August 1956 from various areas of the inner wall for determination of moisture content. Five-gram samples were weighed, dried in an autoclave at 110° C for 24 hours, and then reweighed to determine moisture content by per cent.

WET STUMP HOLE FORMS

As in wet tree holes, the inhabitants of the wet stump hole can be readily grouped or separated by their relationship to the water mass. These groups or forms may be considered as follows: wall forms, surface or surface ring forms, subsurface or aquatic forms, and pedonic forms associated with subsurface ooze and debris according to Snow (1949). In addition to the groups mentioned above, subcortical forms were also noted. While both terrestrial and aquatic microseres were operative in the wet stump hole, the presence of shelf fungi added a conk microsere which could not be studied because of its recent appearance. Park *et al.* (1950) have discussed the role of fungi in tree hole microseres.

DRY WALL FORMS

Generally speaking the inner wall of the wet stump hole harbored a small population in the upper drier portion and a large population in the moist wood from the water's edge upward, downward, and inward (Fig. 2). In the stump hole investigated the dry wall forms were those occurring in pulpy wood about 10-14 in. above the water surface where the moisture content varied from about 10% to 20%. On March 24, 1956, five serropalpid beetles, *Eustrophinus bicolor* (Fab.), were found an inch beneath dry pulp in the wall with several foraging ants, *Aphaenogaster*

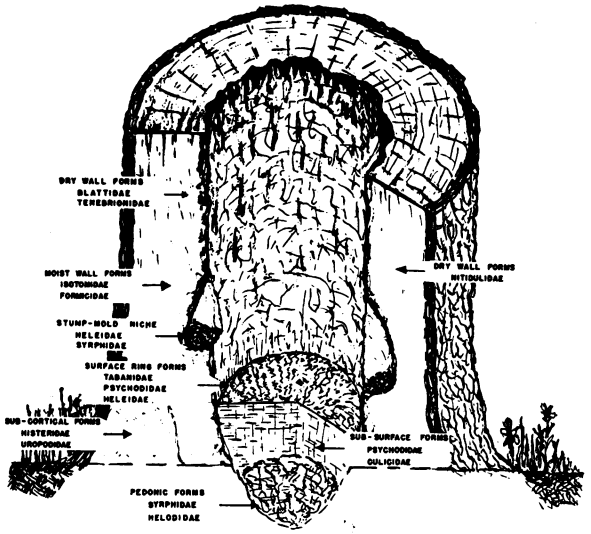

FIG. 2. Diagram of longitudinal section of sweet gum stump at Meadow Pond, Town Creek, Alabama, 1955-1956, indicating location of principal arthropod families.

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lamellidens Mayr. Occasional wood roaches, *Parcoblatta* sp., were also noted as on all other visits. Several orange and black nitidulids were seen crawling in crevices May 12, 1956, but could not be captured. Adults of the mosquito *Aedes triseriatus* (Say) were resting in crevices on May 19, 1956, and occasional black ants, *Ponera coarctata pennsylvanica* Buckley, were crawling about the wall. On June 8, a tenebrionid, *Platydema ruficorne* Sturm., was found with five dermestid larvae in the dry pulp.

Moist Wall Forms

The moist wall forms were found in stump hole mold and fairly intact sapwood varying from about 30% to 73% in moisture content. Those individuals occurring nearest the inner wall (within 2 inches) are cited here, whereas those nearest the outer wall of the stump will be mentioned with the subcortical species. Moist wood of the inner wall exists over a vertical gradient well above and below the water level in the base of the stump. For practical purposes collections of arthropods were limited to the moist wall above the existing water surface and the wet wall at the water surface (surface ring). In prolonged dry periods capillarity often permitted wetting of the wall several inches above the existing water level. Collections from the upper portion of the moist wall approximating the area inhabited by those listed under dry wall forms will be described first. The first collection on March 18, 1955, revealed only one large carabid, *Loxandrus parallelus* Casey. On September 19, 1955, beetles including the following were captured: *Eucinetus morio* LeC. (1) (Eucinetidae), *Dioedus punctatus* LeC. (3) (Tenebrionidae), *Conosoma* sp. (1), *Coproporus* sp. (1) (Staphylinidae), *Epierus pulicarius* Er. (1) (Histeridae), *Tachyura capat* LeC. (1) (Carabidae), and *Baeocera* sp. (1) (Scaphidiidae). Two pseudoscorpions, *Verrucaditha spinosa* (Banks) (Tridenchthonidae) and *Pselaphochernes parvus* Hoff (Chernetidae), were also individually represented. The first collection in 1956 on March 24 revealed a nearly mature larva of *Leucotabanus annulatus* in the upper portion of the moist wall and an adult of the eyed click beetle *Alaus oculatus* (L.) (Elateridae). A nest of the ant *A. lamellidens* was uncovered at a point intermediate in position from the dry wall zone and the water surface and about 2 in. inside the wall. It contained about 30 workers of both sizes. Also present in the nest area were two collembolans, *Isotoma sensibilis* Tullb. (Isotomidae) and *Pseudosinella candida* Fols. (Entomobryidae), the former being very abundant. The following individuals, with emergence dates, were reared from this site in the laboratory: 3 *Coenosia basalis* (Stein) (Muscidae), 3-30-56, 4-1-56; 1 *Zelmira* sp. nr. *mendica* (Lw.) (Fungivoridae), 4-28-56; 3 *Bradysia* sp. (Lycoriidae) 4-28-56; 2 *Ptinella* sp. (Ptiliidae), 4-28-56; and 1 *Thesium cavifrons* (LeC.) (Pselaphidae), 4-26-56. Eggs of a gryllid, *Acheta* prob. *assimilis* F. (s. l.), taken between thin layers of moist wood on March 24, 1956, had hatched, and nymphs (3) had reached the second instar by April 17, 1956, when the specimens were preserved. On April 25, 1956, when this intermediate zone was revisited, no *Aphaenogaster* were seen, but aquatic larvae (6) of an helodid beetle, *Prionocyphon discoideus,* had migrated to this site from the water to pupate. Adult beetles found in the moist wall at this time were *Conosoma* sp. (1), *Coproporus* sp. (1), *E. pulicarius* (2), and *T. cavifrons* (1). A large bluish collembolan, *Isotoma viridis* Bourl., was also present. Two males and one female *Dasyhelea oppressa* Thoms. (Heleidae) emerged from retained wood in the next four days. On May 12, 1956, collections beneath two inches of wood in the upper portion of the moist wall revealed single specimens of the horned passalus *Popilius disjunctus* (Ill.) (Passalidae), the ant *A. lamellidens,* and a female pseudoscorpion, *Parachernes* sp. On May 19 the same position was sampled and the following collembolans recorded: *Pseudachorutes subcrassoides* Mills (3) (Poduridae), *Xenylla welchi* Fols. (1) (Poduridae), *Lepidocyrtus cyaneus* Tullb. (2) (Entomobryidae), and *Pseudosinella candida* (1). One specimen of an endomychid beetle, *Rhanis unicolor* Ziegl., and the pseudoscorpion *V. spinosa* were also found. A single *Aphaenogaster* was seen on the moist wall on May 19; however, when revisited on June 30 approximately 30 specimens were roused from the nest in the moist wall. At the upper end of the moist wall zone and several inches within the wall, two empty puparia of a short-tailed syrphid, *Milesia virginiensis* (Drury), were discovered on June 30. Of the syrphids ordinarily encountered in stump holes and tree holes, *Milesia* appeared to be the least aquatic and its appearance in the upper portion of the moist wall was expected. During the summer of 1955, a female *Milesia* was noted ovipositing in crevices on the inner wall about 8-10 inches above the water surface.

Stump Mold Niches

The stump mold niches were small depressions on the moist inner wall of the stump cavity and contained varying amounts of fine-grained stump mold derived from the immediate wall or from falling particles. These niches were naturally subject to more extreme wetting and drying than

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the inner portions of the moist wall zone. However, because of their proximity to the water surface, they were usually quite moist, at least in the bottom of the niche, and did not appear to range much below 70% in moisture content. In 1955, puparia of the syrphid *Milesia virginiensis* were first collected on May 4, with several adults emerging on May 12. Two additional puparia of *M. virginiensis* taken on May 23 emerged on May 25 and May 27, respectively. On May 15, puparia of *Meromacrus acutus* Fab., a large, long-tailed syrphid, were removed from niches and emerged on May 18 and May 21. A third species of Syrphidae, *Eristalis transversus* (Wied.), was present as a pupa on May 15 and emerged on May 21. One niche sampled on July 8 yielded about 20 larvae and pupae of *Forcipomyia bipunctata* (L.) (Heleidae). Also present was a tabanid larva, *L. annulatus,* which later pupated and emerged on July 20. A larva of the cranefly, *Teucholabis immaculata* Alex., also collected on July 8, pupated and emerged in the laboratory by July 31. During a visit to the stump hole on September 19, 1955, a puparium of what is thought to be *Eristalis transversus* was found in a moist niche and returned to the laboratory for rearing. Two days later, about 50 mixed adults of the genus *Trichopria* (Diapriidae) issued from the puparium in the region of the dehiscent plates. According to Muesebeck (corresp. 1955), they are typical hymenopterous parasites of Diptera always issuing from the pupa or puparium. Due to heavy sampling of the stump mold niches in 1955 only one pocket about 2 in. deep and approximately 6 in. above the water surface was suitable for sampling in 1956. On June 8, a single large tabanid larva, *L. annulatus,* and a puparium of *Meromacrus acutus* were present, the latter species emerging on June 13, 1956.

Surface Ring Forms

A considerable congregation of aquatic and semi-aquatic forms occurs where the water level meets the inner wall of the stump cavity. The upper extent of the ring is determined by the degree of capillarity. In the stump studied, the band of inner wall surface just above the surface film affected by capillarity was considered to be about one inch vertically. The position of the surface ring naturally varies slightly up and down on the inner wall due to periodic addition of rainwater and the depleting effects of evaporation. Moisture content along the surface ring varies from about 75 to 90% and higher. Persistence of fibrous elements of the heartwood on the inner wall adjacent to the water provides for the retention of small pockets of wet mold in a discontinuous circular zone behind the existing surface ring. Actually these small pockets are submerged or partially submerged stump mold niches. When the wet zone immediately behind the surface ring was first examined on March 24, 1956, several larvae of *Leucotabanus annulatus* were discovered (laboratory rearing produced adults on May 12, 13, and 14). Lewis and Jones (*op. cit.*) have noted *L. annulatus* to occupy a similar position in willow stumps. Another larva of *L. annulatus* and a larva of *Meromacrus acutus* were found beneath woody debris just above the water line on an emergent piece of wood in the water. Larvae of the psychodid *Brunettia nitida* (Banks) were numerous in the surface ring on March 24. A sample of wet wood from the surface ring retained in the laboratory until April 10 produced heleid adults of *Dasyhelea oppressa* (14) and *Culicoides arboricola* R. & H. (4), psychodids, *B. nitida* (2) and *Telmatoscopus superbus* (Banks) (1), and an undetermined tendipedid species of the genus *Hydrobaenus* (4). Collembola frequenting this ring on March 24 were *Isotoma viridis* (2). The next visit on April 25 showed *B. nitida* (2), *Culicoides guttipennis* (Coq.) (4), *Hydrobaenus* sp. (3), and *A. triseriatus* (4) present in the late larval or pupal stages. On May 12 larvae of *L. annulatus* (1) and *D. oppressa* (11) were found in a wet pocket behind the surface ring. One puparium of *M. acutus* from this pocket emerged on May 22. Predators, *Acheta* prob. *assimilis* and the pseudoscorpion *Verrucaditha spinosa,* were also present. Two additional puparia of *M. acutus* occurred behind the surface ring on June 8 with emergence on June 13. A recently emerged male helodid, *P. discoideus,* was also noted. One second stage larva of *M. acutus* was taken in a wet pocket on June 30. A final inspection on August 7, 1956, showed 4 pupae of the psychodid *B. nitida,* 2 pupae of *C. arboricola,* and a pupa of the heleid genus *Atrichopogon* present in a three-ounce sample from the surface ring.

Subsurface or Aquatic Forms

The coffee-colored open water in the base of the stump served as a medium for the immature aquatic stages of certain Psychodidae, Heleidae, Culicidae, Syrphidae, and Helodidae. With the exception of the mosquitoes, the other groups represented were able to continue activity even when water had evaporated until only wet debris was present. During the winter the larvae of psychodids, heleids, syrphids, and helodids remained quiescent in ooze and debris beneath the water and ice. On March 24, 1956, water temperatures were still in the low 50's and the main

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activity of aquatic larvae was in the surface ring. By April 25, many second stage and a few fourth stage larvae of *Aedes triseriatus* were present in the water with numerous mature larvae and pupae of *Brunettia nitida*. Again on May 12, larvae and pupae of *A. triseriatus* and *B. nitida* were encountered in the water. Water samples showed larvae of *B. nitida* present on May 19 and pupae of *A. triseriatus* on June 8. No larvae of *A. triseriatus* were found on July 3, but two other mosquitoes had invaded the stump. Mature purple-pigmented larvae of *Orthopodomyia signifera* (Coq.) averaged about 7 per dip with an ordinary drinking dipper. Mature larvae of the predaceous and cannibalistic *Toxorhynchites rutilus septentrionalis* D. & K. were also recovered at about 1 per dip in 4 dips. One pupa of the heleid *Culicoides arboricola* was also collected at the water surface. During a final visit on August 7, larvae of *O. signifera* were still abundant but only one pupal exuvium of *Toxorhynchites* was noted.

Micropedonic or Subsurface Bottom Forms

An ooze layer interspersed with bits of fallen stump mold in various stages of decay is present in the base of the stump beneath the water. During the first visit to the stump hole on March 18, 1955, mature larvae of *M. acutus* (10-12) were found in ooze on the bottom along with many large larvae of *P. discoideus* which were actively crawling about submerged pieces of wood. Two nearly mature larvae of *M. acutus* were recovered at the bottom on July 8, 1955. Larvae of *P. discoideus* (15+) were very active on submerged wood when the stump was visited on March 24, 1956. On April 25, a large larva of *M. acutus* was taken from submerged wood with 20 *P. discoideus*. The *Meromacrus* was returned to the laboratory but did not emerge until August 10. Small numbers of *C. guttipennis* were also present on April 25.

Subcortical Forms

During the course of the investigation the stump has gradually been divested of bark. In 1955 only one casual observation beneath bark revealed an adult of the eyed click beetle *Alaus oculatus*. On May 19, 1956, bark was removed from the base of the stump and mold with moist grass was returned to the laboratory. Later sampling of this site showed the mold to have a moisture content of 84.1%. A variety of mites, collembola, and beetles was found in a 16-ounce sample taken on May 19. The following Coleoptera were present: *Aeletes simplex* LeC. (1) and *Bacanius punctiformis* LeC. (5) (Histeridae), *Thoracophorus costalis* Er. (1) and *Sciocharella delicatula* Casey (2) (Staphylinidae), and *Connophron* sp. nr. *fulvum* LeC. (1) (Scydmaenidae). The collembola were *Xenylla welchi, Pseudachorutes subcrassoides, Lepidocyrtus cyaneus* var. *cinereus* Fols. and *Isotoma cinerea* Nic. The pseudoscorpion *V. spinosa,* and numerous mites in the genera *Galumna* (Galumnidae), *Liroaspis* (Liroaspidae) and *Fuscuropoda* (Uropodidae) were present.

Discussion

Members of the Helodidae, Syrphidae, Culicidae, Heleidae, and Psychodidae encountered in the wet stump hole at Town Creek offer good grounds for comparison with typical inhabitants of wet tree holes in the area. Of the helodids known from wet wood, only *Prionocyphon discoideus* was present in the exposed stump hole. It appears to prefer large cavities in stumps and trees with much mold beneath the water surface. On the other hand, larvae of *Helodes fuscipennis* Guer. and *Helodes pulchella* Guer. are more frequently encountered in dark cavities with leafy debris and often some soil acquired by flooding or wind action.

Larvae of Syrphidae, especially *Meromacrus acutus,* were well represented in the stump hole. At New Orleans, Louisiana, *M. acutus* was taken from dark water in a camphor tree with *H. pulchella*. While *Eristalis transversus* may have invaded the tree cavity in response to small amounts of animal waste which is usual for members of the genus, only two specimens were noted. The absence of *Myiolepta pretiosa* Hull, or as Fluke and Weems (1956) consider it *Miolepta varipes* Loew, from collections in the stump hole is worth mentioning. This species is by far the most frequent syrphid in tree holes over north Alabama and Tennessee. Larvae mature readily in cavities filled with much wet mud as well as in situations with open water and abundant mold beneath. The only short-tailed syrphid collected in the stump hole was *Milesia virginiensis*. The larvae and puparia are usually encountered in the moist wood. However, several larvae were observed suspended from the water surface and feeding below the surface in a wet stump hole at Wilson Dam, Alabama.

Larvae of the mosquitoes *Aedes triseriatus, Orthopodomyia signifera,* and *Toxorhynchites r. septentrionalis* which occurred in the stump hole are regularly found in tree cavities in Alabama and Tennessee. Larvae of *Anopheles barberi* Coq. and *O. alba* Baker are also known from tree holes in the region but are infrequently encountered. Adults of *Anopheles quadrimaculatus* Say and *Anopheles walkeri* Theo. are known to use stump

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holes as diurnal resting sites in this area but do not breed in tree hole cavities.

Larval representatives of the family Heleidae which live beneath the water of tree holes in Alabama and Tennessee are *Culicoides arboricola, C. guttipennis, C. nanus* R. & H., and *C. villosipennis* R. & H. The first two species were found in the stump hole and it is improbable that the latter two species would not normally be found there. Two other heleids, *C. hinmani* Khalaf and *C. paraensis* (Goeldi), which occur in moist, but not wet, cavities in Alabama and Tennessee were also absent at Town Creek. Larvae and pupae of *Dasyhelea oppressa* found in the surface ring of the stump are very common in the moist walls of wet tree holes.

The psychodid *Brunettia nitida* was one of the dominant species of aquatic Diptera taken from the wet stump hole. In tree holes it also prefers large wet cavities with much organic mold beneath the surface and may also be associated with *Telmatoscopus superbus*. Larvae of *T. albipunctatus* (Will.) are occasionally taken in cavities with leafy debris and in artificial containers with polluted water, but they did not appear in the stump hole.

The larvae of a large black and orange marked mydas fly, *Mydas clavatus* Dr., were not found in the stump at Town Creek. They are frequently found in decaying stumps in this region and have been observed beneath bark in an old oak stump at nearby Wilson Dam, Alabama.

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Summary

Observations of a sweet gum stump near Town Creek, Alabama, in 1955 and 1956 showed that the arthropod inhabitants could be segregated into dry wall forms, moist wall forms, surface ring forms, subsurface or aquatic forms, micropedonic or subsurface ooze forms, and subcortical forms.

In the dry wall, wood roaches, serropalpid beetles, and tenebrionid beetles were found. Dominant moist wall representatives were the ant *Aphaenogaster lamellidens* and a collembolan, *Isotoma sensibilis*. Stump mold niches formed suitable breeding sites for the heleid *Forcipomyia bipunctata* and served as pupation sites for the rat-tailed syrphids *Meromacrus acutus* and *Eristalis transversus* and the short-tailed *Milesia virginiensis*. The heleid *Dasyhelea oppressa* and the tabanid *Leucotabanus annulatus* were common in the surface ring area. Typical mosquitoes in water at the base of the stump were *Aedes triseriatus, Orthopodomyia signifera,* and *Toxorhynchites rutilus septentrionalis*. In the subsurface layer of ooze, larvae of an helodid beetle, *Prionocyphon discoideus,* and *M. acutus* were frequently present; however, both species migrated to moist areas of the stump wall for pupation and emergence. In subcortical situations, species of mites in the genera *Galumna, Liroaspis,* and *Fuscuropoda* were very abundant.

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