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Feeding activities of slugs on Myxomycetes and macrofungi

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INTRODUCTION

Myxomycetes commonly referred to as the true slime molds have two stages that may develop into a large enough mass to serve as a potential food source for animals. The plasmodium is a soft, flattened sheet of acellular protoplasm capable of migrating, feeding, and growing up to several meters in length along the surface of decaying logs and leaf litter. Under ideal conditions fruiting bodies that develop from the plasmodial stage may form a single cushion shaped aethalium up to 74 cm across or thousands of individual sporangia less than 1 mm in diameter that may extend for several meters (Keller and Braun 1999).

A wide variety of animals use myxomycetes as a food source. Ing (1967) noted that different groups of invertebrates feed on plasmodia and spores of myxomycete fruiting bodies. The woodlice, *Trichoniscus pusillus*, *Oniscus asellus*, and *Androniscus dentiger*, feed on both plasmodia and mature fruiting bodies of *Trichia varia*, *Arcyria denudata*, and *Didymium iridis*. A millipede *Cylindroiulus punctatus* was observed feeding on sporangia of *Trichia varia*. Nymphal and adult springtails feed on small myxomycete fruiting bodies on bark or wood. Anisotomid beetles feed on mature fruiting bodies of a number of Myxomycetes such as the aethaliate *Fuligo septica*, *Lycogala epidendrum*, *Reticularia lycoperdon*, *Symphytocarpus flaccidus*, and *Tubifera ferruginosa*. Other beetle families associated with Myxomycetes include members of the Staphylinidae, Hydrophilidae, Lathridiidae, Sphindidae, Ciidae, and Endomychidae. Flies in the families Mycetophilidae, Sciaridae, Scatopsidae, Cecidiomyiidae, and Empididae feed or breed on plasmodia and decaying fruiting bodies producing larvae, pupae, and adults.

Keller and Smith (1978) described the feeding activities of an acarid mite, *Tyrophagus putrescentiae*, on a bright yellow sclerotized phaneroplasmodium on living tree bark samples in moist chamber cultures. This mite invaded agar cultures of *Didymium annulispora* and *Stemonitis flavogenita* feeding on the powdery, dark-spored mass. Myxomycete spores were observed passing through the mite's digestive tract and were found in the fecal pellets. Intact spores within fecal pellets were observed germinating in hanging drop slide cultures.

More recently, review articles by Blackwell (1984), Wheeler (1984), and Newton (1984), and studies published by Newton and Stephenson (1990), Stephenson and Stempen (1994), and Stephenson et al (1994) have increased the list of insect and myxomycete species associated with beetle feeding. Many of these newer records of myxomycete species listed are sporangiate and include species of *Stemonitis*, including *S. axifera*.

An unusual example of a vertebrate feeding on a myxomycete was the report of two adult gray jays, *Perisoreus canadensis*, feeding on a large yellow plasmodium of *Fuligo septica* in the Northern Cascades of Washington (Sutherland and Crawford 1979).

Mollusc feeding activity.—Feeding activities of arthropods are well documented in the literature, however, other invertebrates such as molluscs have been studied infrequently, even though they are frequently seen feeding in the field on Myxomycetes and fungi. Eliasson (1981) reported that the snail (slug) *Limax* sp. fed on the pigmented, soft stage of the myxomycete *Symphytocarpus flaccidus*. This myxomycete taxon in general habit is an aethalioid *Stemonitis*. Eliasson's Fig. 11 (A) shows *Limax* with anterior tentacles extended forward feeding on the immature, darkly colored aethalium. This figure is cited as the source for the following statement: ''Snails eat plasmodia as well as fructifications (Fig. 11A) and are probably the reason why plasmodia under regular observation in some cases unexpectedly disappear.'' There is no photograph that documents slugs feeding on plasmodia.

Observations and photographs recorded here of slugs feeding on myxomycetes from ground sites and their discovery for the first time in the tree canopy was part of the All Taxa Biodiversity Inventory and tree canopy biodiversity research projects in the Great Smoky Mountains National Park (GSMNP). The

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FIGS. 1–4. 1. Habit. Mature, reddish brown, stalked sporangia of the myxomycete *Stemonitis axifera* with brownish slug *Philomycus flexuolaris* nearby at bottom; immature, white, stalked sporangia with *Philomycus carolinianus* above. Bar = 1 cm. 2. *Philomycus carolinianus*. Anterior view of slug feeding on soft, white, immature sporangia of *Stemonitis axifera*. Note the preformed stalks that appear as black lines inside the cylindrical spore case. Bar = 1 cm. 3. *Ariolimax columbianus*. Slug feeding on basidiocarp gills of *Pleurotus ostreatus*. Bar = 2 cm. 4. *Ariolimax columbianus*. Slug feeding on basidiocarp stipe of *Boletus edulis*. Bar = 2 cm.

ground site study area consisted of hardwoods such as *Juglans nigra*, *Liriodendron tulipifera*, *Quercus alba*, and a few scattered *Tsuga canadensis* located near the Cades Cove Ranger Station in the eastern end of the park (GPS reading N35° 36.139′; W83° 46.701′). This area was mostly cleared for farming as shown by an aerial view of Cades Cove in 1936 (Shields 1977). Logs in various stages of decay were scattered about this area. A *Quercus alba* log with exposed wood in places with bark sloughing off was the substratum for the slugs *Philomycus carolinianus* and *P. flexuolaris* and the myxomycete *Stemonitis axifera* (FIG. 1).

Observations were made from 10:00 pm until 2:00 am on three successive nights, June 11, 12, and 13, 2001. Conditions were ideal for lignicolous myxomycetes and slugs because of the recent heavy rains and saturated condition of the wood. No rain occurred during this time so the log was gradually drying. Each night *S. axifera* developed numerous colonies of stalked sporangia with soft, milky white spore cases (FIG. 1). Many sporangia of all stages were present each night, including soft reddish-brown pigmented, immature stages and mature, powdery-spored stages (FIG. 1). Aphanoplasmodia were never seen because this type of plasmodium develops in the interstices of the wood and directly forms sporangia at the surface. Each night three to five slugs migrated from underneath the flaps of bark along the sides to the more exposed wood on the upper side of the log. Slugs with extended anterior tentacles moved preferentially toward the immature milky white sporangia, passing by all other more mature stages. This same pattern of migration was observed each night. Slugs fed on the milky white, stalked sporangia, eating each sporangium from the top downward (FIG. 2). Entire groups of the immature sporangia were eaten within two to three minutes. This preference for and selective feeding on the white sporangiate, immature fruiting bodies of *S. axifera*, and avoidance of the more mature fruiting bodies represents a feeding pattern not exhibited by other slug species.

Slugs reacted to flashlight and camera flash. The anterior tentacles were quickly withdrawn and feeding stopped. If total darkness was maintained for several minutes the slugs returned to feeding. Blackwell (1984) noted Quentin Wheeler's belief that the antennae of *Anisotoma* species are used as antennal chemoreceptors to detect Myxomycetes. Slugs appeared to use their anterior tentacles to detect the immature stages of myxomycete fruiting bodies similar to the *Anisotoma* beetles. During daylight hours slugs remained hidden in dark recesses of areas where bark had separated from the wood or on the underside of the log.

Philomycus carolinianus and *P. flexuolaris* belong to a group of terrestrial land snails called slugs, which never develop shells. *Philomycus carolinianus* ranges up to 100 mm when fully extended (Burch 1962) and both species are found in the GSMNP (Hubricht 1985). The geographic range of *Philomycus carolinianus* extends from Maine to Florida and west to Iowa, Kansas, and Texas (Burch 1962, Hubricht 1985). Both species are usually found under the loose bark of partially decayed logs in humid forests.

There are no previously published records of slugs or snails from the tree canopy in the GSMNP. A microhabitat such as a knothole filled with water at approximately 13.7 m high on the trunk of a living *Quercus alba* produced two specimens of *P. flexulolaris*. This species was also associated with a seeping wound on another *Q. alba* at 6.1 m in height. Two specimens of *P. carolinianus* were found at heights of 5.4 and 8.1 m on *Acer rubrum*. In all of these cases the specimens were collected crawling on the bark surface and fissures during daylight hours. Under these conditions the food source of the slugs could not be determined.

There is little information published about the feeding activities of *Philomycus* slugs. Most slug species are generalists, feeding on a broad spectrum of plant tissues in nature such as green leaves from living plants, lichens, mushrooms, decaying vegetation, and even carrion. Slugs will feed on carrots, peas, apples, and cabbage that are offered as a sole food source (Dan Dourson, pers comm). Noteworthy in this regard are the observations of John McGregor in the GSMNP where *P. carolinianus* was observed feeding on the gill edges and cap margins of species of *Russula* and *Lactarius* and the pores of *Laetiporus sulphureus* (pers comm).

The banana slug, *Ariolimax columbianus* of the northwestern United States is the largest species in North America, reaching up to 20 cm in length. This slug feeds on living and decaying vegetation such as roots, fruits, seeds, bulbs, lichens, algae, fungi, animal droppings, and carrion (Harper 1988). Mushrooms such as *Pleurotus ostreatus* and *Boletus edulis* are a frequent food source for this slug (FIGS. 3, 4). Mushrooms are sometimes entirely eaten, including the cap, gills and stalk down to ground level. Other soft tissue basidiomycetes that are eaten include species of *Pleurocybella* and *Agaricus* (Harley Barnhart, pers comm). Some slug species are ''feeding opportunists'' taking advantage of any plentiful food source at any given time.

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