Animal-Fungal Interactions 4[1]: Observations of Coleopteran use of *Ganoderma* and other fungi in the southern Appalachian Mountains

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Abstract: A diversity of North American beetles rely on fungi for a substantial portion of their life cycle, but there has been limited research into the larger ecological implications of these associations. The dieback of eastern hemlocks (*Tsuga canadensis*) has led to an increase in the fruiting numbers of the shelf fungus *Ganoderma tsugae*; in some areas, this has in turn caused an increase in the populations of pleasing fungus beetles (*Megalodacne heros*).

Key Words: *Adelges tsugae, Cryptoporus*, fungivory, *Megalodacne, Tsugae*, mycophagy

Insect-fungal interactions are highly diverse and fulfill a remarkable number of ecosystem functions ranging from parasitism to symbiotic associations. The use of fungi in the diets of arthropods is well documented and is an important mechanism of spore dispersal for many fungi around the world (Meurant 2012; Koch & Aime 2018). Some plant pathogens form symbioses with beetles; the association between ambrosia fungi (Ophiostomatales) and ambrosia beetles (Curculionidae) is an example of this (Carrillo et al. 2014). Many fungi are eaten by vertebrates and invertebrates and have evolved specialized predation/dispersal associations (Fogel & Trappe 1978; Meurant 2012, Caldwell et al. 2005; Elliott & Elliott 2019; Elliott & Vernes 2019). Stinkhorn fungi, for example, release pungent aromas that attract flies that in turn disperse fungal spores (Tuno 1998). By eating insects that have consumed fungi, some birds act as secondary dispersers of spores (Watson & Shaw 2018). Leaf cutter ants farm fungi for the basis of their diet (Chapela et al. 1994).

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[1] See References for compete citations to Parts 1-3: Elliott & Marshall 2016; Elliott et al. 2018; Elliott et al. 2019.

During the warm season in the Appalachian Mountains and southward, the author has rarely found oyster mushrooms (*Pleurotus* spp.) without a multitude of brown and black adult *Triplax* spp. (Figure 1a) living and breeding within the gills. The most commonly encountered species in the Appalachians seems to be *T. thoracica,* though multiple species in the genus feed heavily on *Pleurotus* (Goodrich & Skelley 1993). For some *Triplax* species, *Pleurotus* is the primary larval food (Goodrich & Skelley 1993).

The arthropod order Coleoptera forms an immense array of associations with fungi, some of which are highly specialized and others which are more opportunistic (Schigel 2012). In Cascades National Park in Chelan County, Washington, the author has encountered at least four genera of beetles (adults and larvae) in the cavities between the lower exterior membrane and the fertile layer of the polypore fungus *Cryptoporus volvatus.* The beetle genera involved included *Aphenolia*, *Epuraea, Neoennearthron,* and *Temnoscheila*. A 2010 study that examined 8990 insects that emerged from *C. volvatus* found 17 different insect species, 11 of which were beetles (Kadowaki 2010). These groups of beetles are not necessarily obligates with this or other species of fungi; however, the enclosed fruiting body morphology of this fungus makes it rely heavily on invertebrate dispersal of its spores. In some situations, woodpeckers have been observed tearing into these fruiting bodies to eat the insects residing within (Watson & Shaw 2018); this behavior suggests that birds are acting as secondary dispersers.

On the opposite end of the specialization spectrum is the beetle *Bolitotherus cornutus,* which depends almost entirely on the fruiting bodies of the polypore *Ganoderma applanatum* and occasionally members of the *G. lucidum*/*G. tsugae* complex (Liles 1956). The author has encountered this beetle in scattered high elevation locations in the Appalachian Mountains, primarily in the Canaan Valley of Tucker County, West Virginia, and in Mitchell County, North Carolina. Based on the author's observations in these regions, *B. cornutus* feeds exclusively on *G. applanatum* (Figure 1b). Beetle mycophagy assists with spore dispersal, but fruiting bodies with non-enclosed fertile surfaces are also able to disperse spores via the wind.

Field observations for this note were made during the peak fruiting season of *Ganoderma tsugae* throughout the southern and central Appalachian Mountains between 2010 and 2017. Seasons

differed depending on region, elevation, and climatic conditions of the specific year, but observations were generally made between mid-May and late August. Any time mycophagy was observed, the behavior was photographed and described. The fungi and beetles were also examined for key taxonomic characters to confirm that they were the target species.

Due to the recent invasion of the hemlock woolly adelgid (*Adelges tsugae*) through much of the southern Appalachian Mountains, there has been significant dieback in eastern hemlock stands over the last decade (Orwig et al. 2012). With the increase in dead hemlocks, there has consequently been an increase in the abundance of the hemlock reishi mushroom (*Ganoderma tsugae*) that specializes in decomposing dead *Tsuga* spp. In some valleys in North Carolina where the author has observed major hemlock dieback (specifically in Buncombe and McDowell Counties), there has been a gradual increase in numbers of *G. tsugae* fruiting bodies. Over the last seven years, the author has also observed an increase in the numbers of pleasing fungus beetles (*Megalodacne heros*) feeding on these hemlock-associated polypores (Figure 1c,d). The author has observed that *G. tsugae* is the principal food of this beetle in this region, and others have found this to be true elsewhere in North America (Goodrich & Skelley 1991). Eastern hemlocks sometimes form sizable monodominant or nearly monodominant stands, but in some of these areas, the adelgids have killed off the majority of the trees. This leads to a correlation between hemlock dieback and greater numbers of *G. tsugae* fruiting bodies; consequently, *M. heros* populations to rise. This may also be true for *M. fasciata* and other mycophagous Coleoptera, but the author has not observed this. There are now mounting efforts to chemically or biologically control the adelgid populations; how this will impact the population numbers of *M. heros* is yet to be determined, but it is a compelling area for further study.

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Fig. 1 A variety of Appalachian beetle species feeding on fungi. **a.** *Triplax* spp. residing between the gills of an oyster mushroom. **b.** Two adult *Bolitotherus cornutus* feeding on the pore surfaces of a young *Ganoderma applanatum*. **c.** *Megalodacne heros* chew marks on the upper surface of large fruiting bodies of *Ganoderma tsugae*. **d.** Adult *M. heros* on the upper surface of a *Ganoderma tsugae* fruiting body. Note the pockets on the margin of the cap that have healed over after fungivory occurred.