Biological Control of Winter Moth in Massachusetts

Project Report
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Introduction

In eastern Massachusetts, widespread defoliation by geometrid larvae originally thought to be the fall cankerworm, *Alsophila pometaria,* has occurred yearly for at least six years. The fall cankerworm is one of several species of geometrid moths that feed in early spring and produce flightless adult females that emerge, attract winged males and lay eggs in November (fall cankerworm) or April and May (spring cankerworm, *Paleacrita vernata*). A large-scale flight of male moths that occurred in late December 2002 prompted the recognition that these geometrids might not be fall cankerworm at all, but instead might be either winter moth, *Operophtera brumata*, which is native to Europe, or its North American congener, the Bruce spanworm**,** *Operophtera bruceata.* Definitive identification of this outbreak species as winter moth and not Bruce spanworm was provided in December 2003 by Dave Wagner at the University of Connecticut and by Richard Hoebeke of Cornell University.

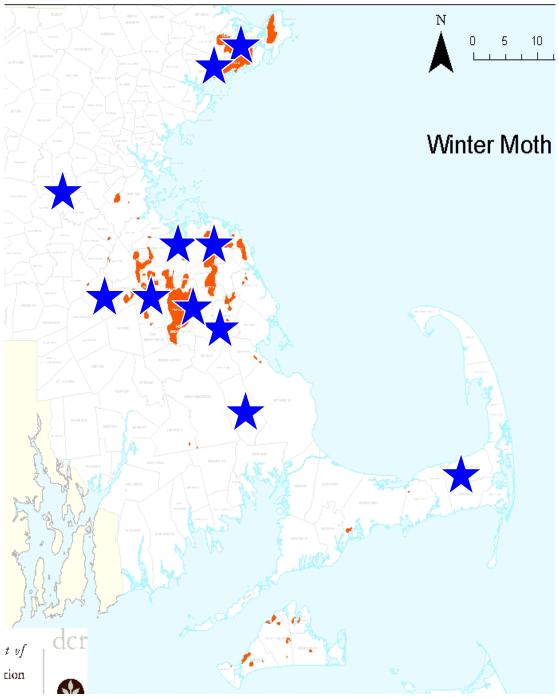
Invasions of winter moth have occurred at other sites in North America, namely Nova Scotia in the 1950s (Embree 1966, 1991) and in the Pacific northwest in the 1970s (Roland 1986). In each case, a decade-long outbreak has been successfully and permanently controlled by the introduction of a tachinid parasitoid, *Cyzenis albicans,* from Europe (Embree 1966, Roland 1986, Roland and Embree 1995). This species is highly specialized on winter moth. The success of these introductions was a surprise to earlier European investigators, whose work had shown that low density populations of winter moth are maintained largely by generalist beetle predators of the pupal stage in the soil (Varley 1968, Varley et al. 1973). Subsequent research, however, confirmed the importance of *C. albicans* in North America (Roland 1986, Roland and Embree 1995). It has a biology similar to *Blepharipa pratensis* on gypsy moth, in that it lays microtype eggs on the foliage surface that must be consumed by larvae and the adult flies aggregate to trees where defoliation by winter moth is occurring. As such, it is effective mainly in causing the collapse of high-density populations, and in this respect plays a vital role in suppressing outbreaks. Given the extended multi-year outbreak of winter moth in eastern Massachusetts, we expected that we would find that *C. albicans* is not here. That is exactly what we have found this year.

C. albicans is one of two parasitoid species introduced to control winter moth and successfully established in North America. The ichneumonid *Agrypon flaveolatum* was released in Nova Scotia and in the Pacific Northwest. It did not establish in Oregon, and it caused lower mortality than *C. albicans* in Nova Scotia and very low mortality (1-2%) on Vancouver Island.(Roland and Embree 1995). It is also much more polyphagous than *C. albicans*. For these reasons, we will focus on *C. albicans*, at least initially.

***Objective 1: To determine the parasitoid species currently attacking winter moth life stages and to measure percent parasitism from various sites across the range of winter moth in eastern Massachusetts. In particular, to document the presence or absence of C. albicans and* A. flaveolatum.**

In late May 2004, we collected late-instar winter moth larvae from about 20 sites spread widely across the current geographical range of winter moth in Massachusetts (Fig. 1A), from Manchester by the Sea, on Cape Ann, north of Boston to Brewster on Cape Cod. We reared 3,696 of these to the pupal stage and inspected them in midsummer for visual signs of parasitism. None of them appeared parasitized by *C. albicans* or any other parasitoid. These pupae were again inspected in late fall, and two tachinid fly pupae were found, neither of which were of the genus *Cyzenis* (identified by G.H. Boettner). Some of these pupae had been used in our late-summer studies of pupal predation, but we reared 2281 to the adult stage. We dissected any pupae that did not yield an adult moth. None were parasitized. We thus conclude that neither *C. albicans* nor *A. flaveolatum* were introduced along with the winter moth into eastern Massachusetts, and are not currently present in the population. No parasitoid species emerged from the larvae that we reared or from winter moth eggs that we reared the previous year. The winter moth population is thus remarkably and disturbingly free of parasitism. We did note some larvae dying from an unknown disease agent. We autopsied the cadavers of these caterpillars and sent some to Ann Hajek at Cornell University and Jim Slavicek of the USFS Delaware Ohio lab. Neither of these individuals detected virus (NPV) in these cadavers. The cause of death remains unknown, but we will pursue identification of this agent in the coming year. No previous study of winter moth has identified any pathogens as a major cause of death. It is known to have a virus disease similar to that of gypsy moth, but I am not aware of any report of virus epizootics in winter moth populations.

Fig 1A



1B

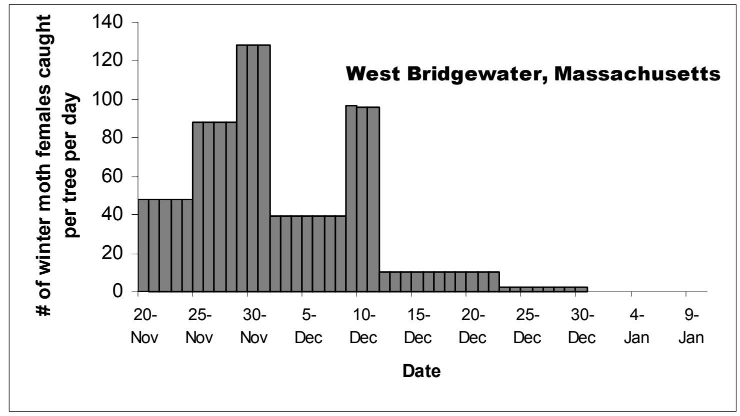


Figure 1: 1A) Map of eastern Massachusetts showing areas defoliated by winter moth in 2004 (in red) and winter moth collection sites (blue stars). 1B) Numbers of female winter moths captured on two sticky bands wrapped around the stem of a single tree in West Bridgewater, Massachusetts. The bands were changed as needed when they filled up. A total of 1619 total female winter moths were caught over the entire emergence period on this tree.

Objective 2: To establish winter moth population monitoring plots in which we will measure density of winter moth life stages in order to establish baseline data against which we will document the effects of a future biological control release or to understand why winter moth has remained at high density if we find that C. albicans is already here.

Study Plots:

This part of the project constitutes the masters degree research conducted by Brenda Whited in Joe Elkinton’s laboratory at the University of Massachusetts. In late April of 2004, we established 20 focal trees on the South Shore of Boston to measure the winter moth density at various life stages. A previous study in Nova Scotia (Embree 1965) showed greater defoliation in red oak and lower larval survival on red maple. In eastern Massachusetts, red maples are reportedly more heavily defoliated than red oak. This may suggest that winter moth egg hatch is more closely synchronized with red maple budburst than with red oak budburst (Embree 1965, 1991). To investigate relative density and survival of winter moth on these two host tree species, we chose 10 red maples (*Acer rubrum*) and 10 red oaks (*Quercus rubra*). Five of each species grow on a lawn and five occur on a forest edge. We expect that lawn vs. forest edge may have a great effect on pupal mortality, as winter moths pupate in the soil, and predacious beetle communities may vary dramatically between these two habitats.

Measuring densities of winter moth larvae and pre-pupae

On each of the trees we made counts of early instar larvae per bud in the first week of May. In late May, we estimated pre-pupal density using numbers of pre-pupae falling into collection trays positioned randomly beneath the tree canopies. In addition, we estimated percent defoliation of each tree. As described below, we also made estimates of adult females climbing each of the trees in November and December. These numbers will allow us to construct life tables for the winter moth populations on each tree using the procedures pioneered by Varley and Gradwell (1968, Varley et al. 1973). We found that maples had a higher density of early instar larvae than oaks, and site (lawn vs. forest edge) had no effect.

Estimating Adult Density:

Winter moth adults began emergence in late November. On November 20th we deployed sticky bands purchased from Envirometrics Systems Inc. to collect female winter moth climbing the tree trunk to oviposit. We placed two bands on each tree to get a sense of how well the bands were working, because any moths captured on the upper bands would have to traverse the lower band first. Because we want to measure winter moth our focal trees for years, before and after the introduction of *C. albicans*, we did not want to catch the entire population of females on our focal trees. Thus, we censused the entire population of females on two other nearby trees from November 20th until early January, and put sticky traps on our focal trees for only one 24 hour period during peak flight. This one-day of flight represented about 5% of the total winter moth emergence.

With the help of Deborah Swanson and Don Adams we changed the sticky bands several times a week on two trees, one in Hanson, Massachusetts and the other in West Bridgewater, MA during the adult flight season. We counted all females captured on those bands during that entire time. On the tree in West Bridgewater we counted 1619 female winter moths and on the tree in Hanson Mass we counted 1014 winter moths. Since each female lays about 150 eggs, that means that 1619 females will lay about 243,000 eggs on that one tree. This represents only the females that we caught. An unknown number managed to traverse the bands. We know this because the upper bands caught almost as many females as the lower bands. If you multiply one quarter million eggs per tree times however many million trees are infected, you arrive at a winter moth population size in the trillions!!

Pupal Predation

Various studies (Varley and Gradwell 1973, Pearsall and Walde 1994, Roland 1994) show evidence that mortality of pupae in the soil is density dependent and may regulate low-density winter moth populations. This mortality includes predation by generalist ground dwelling predators and studies conducted in endemic populations of England show spatial density dependent mortality caused by beetle and small mammal predation (Frank 1967, East 1974). However, one study (Raymond et al. 2002) investigated the role of pupal predation in *high*-density outbreak populations in England, and found inversely density dependent pupal predation. The implications were that outbreak populations had overwhelmed and escaped the regulatory abilities of predators that occur at low density. This is a typical pattern for outbreak species including gypsy moth.

To measure predation rates we placed out winter moth pupae beneath eight of our focal trees in midsummer. We retrieved them about two weeks later and determined the proportion that had been consumed by predators. We are interested in the role of pupal predation in Massachusetts's outbreak populations. Do predation rates decline as winter moth density increases, as found in high-density populations in England (Raymond et al. 2002)? To date our results are equivocal, and we plan to repeat the experiment next year.

Conclusions and Future work

Based on previous experience in Nova Scotia (Embree 1965, 1991), it is likely that winter moths will continue to defoliate trees in eastern Massachusetts on a yearly basis. It is unlikely that winter moth populations will decrease until after the introduction of *C. albicans.* Embree and colleagues released several thousand individuals of these parasitoids at several sites beginning in 1955. Parasitism began to build up and the winter moth started to decline in 1960. The reason for this lag time is not hard to understand. Even if the parasitoid populations expand exponentially at a 100 fold per year, it would take a few years before a few thousand parasitoids expanded to catch up with a winter moth population that numbers in the billions if not trillions. It is imperative that we begin collection and rearing of *C. albicans* this year and that we mount a sufficiently sizeable effort to permit releases in the thousands and releases at a number of sites spread across the infested area. Collections of *C. albicans* from the low-density populations that exist in Nova Scotia and in British Columbia are labor intensive. I found this out first hand in Nova Scotia last June. In four days of work from dawn to dusk I collected about 400 winter moth larvae. A total of 266 of these larvae survived to the pupal stage. Of these only 10 were parasitized. This result was not unexpected. Pearsall and Walde (1994) showed that parasitism by *C. albicans* in Nova Scotia was 5-10% in the low-density populations that follows the collapse from high density. These levels of parasitism are far lower than that achieved when the high-density winter moth populations are starting to decline (Embree 1965).

The 10 *C. albicans* individuals I collected are now being held at the USDA Quarantine facility at Otis Air Base. Our plan is to rear these in cages and parasitize large numbers of winter moths ready for release in the spring of 2006. We are also planning to mount a substantially more robust collection effort in Nova Scotia this coming spring. In the meantime, we will continue to monitor winter moth populations on our focal trees, before and after parasitoid introduction and continue to measure parasitism and disease mortality among larvae collected from across the winter moth range in Massachusetts.

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