

LIKELIHOOD OF INFESTATIONS BY *TINEOLA BISSELLIELLA* (LEPIDOPTERA: TINEIDAE) FROM NATURAL RESERVOIRS

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Abstract The webbing clothes moth *Tineola bisselliella* is economically the most import pest on wool, fur, and feathers. The larvae cause damage in stores, museums and households. Infestation can be through import of infested material or by new infestations out of natural reservoirs. Natural reservoirs are believed to be bird, rodent or insect nests. Rearing experiments with collected different nesting materials have shown that *T. bisselliella* is capable to breed in animal nests as well as on stored seeds. Outdoor trapping with pheromones for catching males or with attractive food for the larvae to catch females indicate that the presence of *T. bisselliella* outside buildings is very limited. Although the webbing clothes moth has the potential to survive in non-synanthropic environments, it does not frequently occur there. Intra-guild competition with other tineid moths prevents *T. bisselliella* from establishing sustainable outdoor population. New infestations from the field are unlikely and preventive control must focus on quarantine to avoid the pest's introduction via contaminated material.

Key words clothes moth, invasion, animal nests, quarantine, out-door trapping.

INTRODUCTION

The common or webbing clothes moth *Tineola bisselliella* (Hummel) is one of the most destructive pest insect world-wide of wool, hair, feathers, furs, or articles manufactured from these materials (Kemper, 1935; Flint and McCauley, 1937; Turner and Walden, 1937; Back, 1940; Hinton, 1956; Becker, 1983; Rajendran and Parveen, 2005). In homes, frass by clothes moth larvae leads to quantitative and qualitative damage in woolen fabrics, clothing, and upholstered furniture (Parker, 1990). In drapery shops and rug stores, clothes moth infestations can cause economic losses (Hammers, 1987). *Tineola bisselliella* is also considered a severe museum pest because it infests and destroys ethnological and natural history exhibits which usually contain unique and precious artefacts (Pinniger, 1994).

Control measures to hinder larvae from feeding or to kill intruding flying adult moths of *T. bisselliella* are manifold and include use of insecticides, fumigants, extreme temperature, traps and the release of parasitoids (Bry and Simonaitis, 1975; Florian, 1987; Parker, 1990; Trematerra and Fontana, 1996; Plarre et al., 1999; Pinniger, 2010). However, prevention of new infestations from the beginning would be the key strategy and is an essential part of any IPM program. Although several observations and monitoring studies had been carried out (Child and Pinniger, 1993; Brand and Wudtke, 1997) the pathways of new infestation for this pest remain obscure. For clothes moths two major scenarios for new outbreaks can be thought of: import of infested material or invasion out of reservoirs from the outside. The later requires sustainable moth populations in the natural environment and an excellent mobility by the adults. We have tested the likelihood of *T. bisselliella* occurring outside buildings away

from direct synanthropic conditions which are usually found in homes, stores or museums. We have set up pheromone-traps and artificial nest-traps out-doors to catch migrating male and female adult moths (Robinson, 1988a). We have collected empty nest material from birds and insects and inoculated these with eggs of *T. bisselliella* to check for their developmental potential on these substrates respectively diets. We critically analyzed published faunistic records of clothes moth findings in bird nets.

MATERIAL AND METHODS

Pheromone traps. Outdoor pheromone trapping was carried out in two consecutive years from August 2008 to July 2010. Several trapping locations, 23 in the first and 13 in the second year, were set up within and outside the city limits of Berlin (Germany). The sticky traps were placed outside buildings but in sheltered areas. Traps contained a sex-pheromone lure for *T. bisselliella* provided by Insects Limited (Indianapolis, USA). Trap catches were checked and lures were changed on a biweekly basis. **Artificial nest-traps.** Artificial nests were made of goose quills which had been soaked in 10 % nutritional yeast/water solution and oven dried. This material has successfully been used for rearing *T. bisselliella* in the laboratory at BAM. Quills were loosely packed into a plastic bucket (12 cm in diameter, 12 cm in height) which was placed into a modified wooden bird box (18 cm x 18 cm base area, 22 cm in height) with an entry slit (Figure 1). Similar to the pheromone traps, artificial nests were placed in sheltered areas outside houses in and near Berlin at 9 locations (Table 1). Prior to that, tests at ca. 25°C and 65% RH in a laboratory flight room (5 m x 2 m x 2 m) revealed the principal suitability of the trap design to catch webbing moth females (Plarre, 2011). Traps were checked and replaced by new material on a quarter-yearly basis for two year (August 2011 to July 2013). After initial visual trap inspection for insects the artificial nest-material was incubated at rearing conditions of $27 \pm 1^\circ\text{C}$ and $75 \pm 5\%$ RH. in the laboratory to allow development of any instars with a final check after 6 weeks.

Table 1. Qualitative evaluation of trapped *Tineola bisselliella* in artificial nest traps at different locations in and around Berlin, Germany for two years.


trapping location	short description of location (number in brackets corresponds with trapping location of figure 2)	<i>T. bisselliella</i> trapped (yes or no)
city center  country side	urban-city, multifamily house, balcony 1 st floor (-)	no
	urban-city, multifamily house, balcony 2 nd floor (14)	yes
	suburban, multifamily house, balcony 5 th floor (12)	no
	suburban, single family house, backyard (10)	no
	suburban, single family house, backyard (8)	no
	suburban, single family house, backyard (9)	no
	urban fringe, single family house, backyard (-)	no
	urban fringe, single family house, backyard (-)	no
	landscape area, single family house, backyard (20)	no

Table 2. Development of *Tineola bisselliella* from egg to adult on different breeding materials.

Material tested for development of <i>T. bisselliella</i>	Development from egg to adult
blue tit <i>Cyanistes caeruleus</i> nest foundation, plant material only	2 replications with no successful development
blue tit <i>Cyanistes caeruleus</i> breeding nest with dead mummified chicks	1 replication with 1 successful development
empty wasp nest <i>Vespula vulgaris</i> with insect debris	1 replication with 1 successful development
insect corpses of adult European house longhorn beetle <i>Hylotrupes bajulus</i>	2 replications with 2 successful developments
insect corpses of adult webbing clothes moths <i>Tineola bisselliella</i>	3 replications with 1 successful development
insect corpses of adult case bearing clothes moths <i>Tinea pellionella</i>	3 replications with 2 successful developments
wheat kernels <i>Triticum spec.</i>	1 replication with 1 successful development
wheat kernels <i>Triticum spec.</i> with insect corpses of adult grain weevils <i>Sitophilus granarius</i>	2 replications with 1 successful development
insect corpses of alate dry wood termites <i>Incisitermes marginipennis</i>	2 replications with 2 successful developments
insect corpses of alate dry wood termites <i>Koloterms flavicollis</i>	1 replications with 1 successful developments

Breeding experiments. A number of different substrates were tested whether *T. bisselliella* was capable for a successful development from egg to adult. The materials were collected by chance or were byproducts of the BAM multi insect rearing facility. They are not considered exhaustive nor exceptional representative. All material may be encountered in natural reservoirs (Table 2).



Figure 1. Artificial nest trap in modified wooden bird box to attract females of *Tineola bisselliella*. The plastic cup contained yeast soaked and oven dried goose quills, a substrate suitable for larval development and thus attractive to egg-laying females.

RESULTS AND DISCUSSION

Pheromone traps. Figure 2 (2A for 2008/2009 and 2B for 2009/2010) shows cumulated catch data of trapped male moths per year and per trapping location arranged from city center (left) to country

side (right). The further away from the city the fewer was the number of *T. bisselliella* captures up to total absence of this species in the country side. Interestingly, besides negligible by-catches one other tineid moth, the brown-dotted clothes moth (*Niditinea fuscella* L.), was caught in also high amounts. It is known that males of this species are attracted to alcohol compounds (Hwang *et al.*, 1978), and most likely they were lured into the trap by the webbing clothes moth pheromone's solvent. The brown-dotted clothes moth is a typical species from bird nests in Central Europe and trapped with alcohol based lures (Trematerra and Fiorilli, 1999). Trap catches of *N. fuscella*, were reciprocal to those of *T. bisselliella* with highest numbers in the country side.

Artificial nest-traps. Table 1 shows presence or absence of clothes moths in nest traps after initial visual inspection and after incubation. Trapping locations are arranged from city center (top) to country side (bottom). Clothes moths were caught in only one single trap located in the city center. All other traps lagged the presence of this species. Because the principal suitability of the trap design to catch flying webbing clothes moth females had been demonstrated in the laboratory, it is believed that in this survey female moths were either not present in the respective out-door environment or the overall abiotic seasonal conditions regarding temperature and humidity prevented extent flight behavior (Titschack, 1925; 1927; Griswold, 1944). Regardless of the reason, female *T. bisselliella* appear not to extensively commute out-doors.

Breeding experiments. *Tineola bisselliella* was capable of successful development from egg to adult on any of the tested material of animal origin (Table 2). Keratin, a fibrous structural protein, was believed to be essential and obligatory for clothes moth development (Robinson, 1988b). Our rearing experiments on insect corpses, however, suggest that chitin can serve equally well. Thus accumulation of insect debris which may occur in seasoned insect nests (bees, wasps, ants, termites) must also be considered as excellent breeding reservoirs for *T. bisselliella*. Even starch dominated material of purely plant origin like wheat seeds seem to allow complete development of this moth species (Table 2). Findings by Ishii and Kawahara (1966), Becker (1980), Sellenschlo (1990) and Stejskal and Horak (1999) support the oligophagous potential of *T. bisselliella*, which can be regarded as a pre-adaption to successfully invade the synanthropic environment. In our experiments only the base-nest of the blue tit which was made of small wooden sticks and moss was not suitable for clothes moth development.

Review of faunistic records. Reports in the literature regarding the presence of *T. bisselliella* in natural habitats away from human housings are rare and confusing. For example, in his summary of bibliographies on nidicolous insects Hicks (1959) lists 15 references to *T. bisselliella* findings in bird nests. Thus, in secondary and tertiary literature, it is often listed as a common species in bird nests (Niethammer, 1937; Uhlmann, 1937/1938; Hinton, 1956, Petersen, 1969; Hannemann, 1977; Klausnitzer, 1988; Pinniger, 2001; Cox and Pinniger, 2007). Our own studies of the listed references, however, do not allow for this general conclusion. First one notices duplications of citations as well as generalized faunistic reports from secondary literature without specified data. This limits the number of original works reporting the presence of webbing clothes moths in bird nests to only six references (Boyd, 1936; Herfs, 1936; Kemper, 1938; Büttiger, 1944; Woodroffe and Southgate, 1951/1952; Woodroffe, 1953), The abundances of webbing clothes moth individuals in these finding are all very small (Weidner, 1961).

Indirect negative reports on *T. bisselliella* exist: Nordberg (1936) did not find any webbing clothes moths in a total of 422 nests of various bird species, while he did find large numbers of other moths including *N. fuscella*. Hinton (1956) never found webbing clothes moth in bird nests. Similarly, the webbing clothes moth is not listed in the results of the faunistic investigations by Green (1980) and Krall (1981).

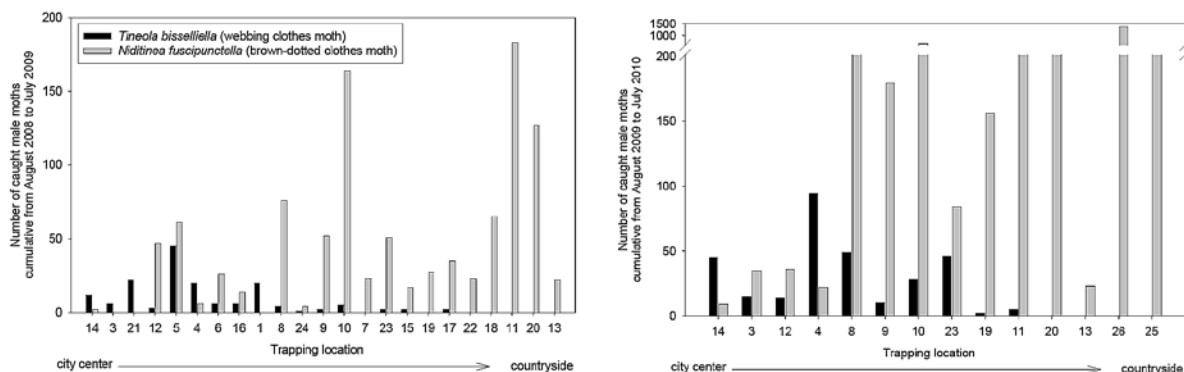


Figure 2. Pheromone trap catches of *Tineola bisselliella* (black bars) and *Niditinea fuscipunctella* (grey bars) at trapping locations in and around Berlin, Germany, from city center to countryside. Numbers of trapped male moths are cumulated for each location and year (1st year left and 2nd year right).

CONCLUSION

It is generally accepted that the natural habitats of most pest insects can be found outside the synanthropic environment in layers of leaf litter, under bark, as well as in rodent or bird nests. Indeed, most of the common pests have been reported as being facultative nidicolous (Linsley, 1944). Therefore infestation of commodities by pest insects out of these reservoirs is one considerable possibility. However, the likelihood of a pest's occurrence and survival out-doors largely depends on its ecological potential and competitiveness against other species of the same ecological guild. Some pest species are rarely found in wild habitats, especially in those regions where they are not native and where they have been introduced by man.

The fabric pest *T. bisselliella* serves as a good example. Most likely originating in Central or Southern Africa this insect was introduced into Europe probably not earlier than the late 18th century (Weidner, 1970; Plarre and Krueger-Carstensen, 2011). Being more tolerant to dry environments than other fabric pests its economical importance increased during the 20th century when in-door climates changed because of central heating systems. *Tineola bisselliella* should be regarded as an eusynanthropic species. Its occurrence in out-door natural habitats must be regarded as accidental. Reported founds of webbing clothes moth larvae in bird nests have been largely overstated in the literature. Although theoretical possible, *T. bisselliella* must be considered to be an exception and a seldom to very seldom occurrence in animal nests of paleoarctic biocoenoses. The females' very poor flight ability at moderate temperatures (Hinton, 1956), as well as the strong competition from other species in natural habitats may be the causes. Other tineid moth, especially of the *Tinea*-group and several dermestid beetle species of *Anthrenus* and *Attagenus* are the most common keratinophagous nidicolous insects found in mild climate zones (Hicks, 1959; Petersen, 1963). Economically relevant new infestations by *T. bisselliella* occur through the displacement and receipt of infested materials. Therefore good quarantine measures are key requirements to prevent damage.

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