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# Arthropod communities of laying hen houses: An integrative pilot study toward conservation biocontrol of the poultry red mite *Dermanyssus gallinae*

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A B S T R A C T

The poultry red mite (PRM), *Dermanyssus gallinae* (de Geer), is a hematophagous mite of economic importance in the poultry industry. Because PRM lives off-host in habitats potentially shared by many micropredators, biocontrol agents have potential to regulate this pest in poultry buildings. The present pilot study was conducted to obtain a first insight into predatory and parasitic arthropod communities that naturally occur on layer farms in France. Species composition and sensitivity to insecticides were determined to estimate the feasibility of conservation biological control (CBC) of PRM based on a 2-scale concept (regional and local effects). A morphomolecular approach was used to characterize the taxonomic composition of manure-dwelling arthropod communities, with a focus on mesostigmatid mites, that naturally occur in free-range layer farms. Additionally, the sensitivity of some dominant mite species to a common insecticide (deltamethrin) was measured via bioassays. The putative roles of recorded taxa within ecological guilds and their dispersal habits are discussed based on the results of multivariate and univariate analyses. Local and regional factors had significant effects on both high-level taxonomic arthropod groups and mesostigmatid morphospecies. In addition to documenting the occurrence and apparent establishment of highly mobile arthropods in hen houses, these results are considered promising for the development of CBC against PRM. Populations of two recurrent mesostigmatid morphospecies demonstrated an extreme sensitivity to the pyrethroid, suggesting that even very low levels of insecticide use are likely to have unnoticed deleterious effects on natural regulation processes in layer buildings. Lastly, a robust method for exploring mesostigmatid mite communities in manure is provided.

## 1. Introduction

Although biological control of pests has been widely developed for dozens, if not hundreds of years, on commercial crop farms, it remains far from full implementation in livestock farming, particularly in Europe. Bale et al. (2008) distinguish the three following primary techniques of biological control: classical biological control, augmentative or 'inoculative' (often involving inundative releases with commercialized, mass-reared agents) biological control, and conservation biological control (CBC, which refers to encouraging indigenous natural enemies). Biocontrol practices are less common in European commercial animal farms and are almost exclusively based on augmentation: for instance, inundative releases of a fly parasitoid on Danish cattle and pig farms (Skovgård and Nachman, 2004) and assessment of two predatory mite species against poultry red mites, *Dermanyssus gallinae* (de Geer, 1778), in lab trials (Lesna et al., 2012). Manure attracts many predatory arthropods which benefit from the diversity of manure-dwelling invertebrates (e.g., nematodes, fly eggs and larvae, among others). In the USA, some of these predators have proven useful for the control of non-hematophagous arthropods such as filth flies, indicating promise for control on caged-poultry farms (Axtell and Arends, 1990; Hinton and Moon, 2003). More manure is allowed to accumulate in barn systems with slatted floors, in which the manure pit is emptied and cleaned up only when layer hens are spent, than in cage systems where manure is removed weekly via a motorized belt systems (Lay et al., 2011). Compared to broiler production flocks that typically last 1–2 months (Goliomytis et al., 2003), egg-producing hens in layer houses typically last a twelve-month period (Food and Agriculture

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Organization of the United Nations (FAO) (2003)). Therefore, CBC holds more promise for non-cage layer systems in which manure accumulates over long periods.

CBC relies on naturally occurring ecological processes and aims to enhance these. This approach was developed in crops with the integration, among other factors, of semi-natural habitats that benefit natural enemy populations by providing alternative food supplies, shelter from disturbance and predation, an improved microclimate, or increased over-wintering survival and reproduction (Begg et al., 2017). The success of such local conservation strategies depends on interactions with meta-populations or communities that are defined at a larger, regional scale: "implicit in the introduction of beneficial habitats is the assumption that the natural enemies will not be restricted to these new habitat patches but will disperse or 'spillover' into other adjacent or nearby habitats including cropped areas" (Begg et al., 2017). However, complex spatio-temporal dynamics and intricate multi-level trophic interactions at the landscape level make success of CBC largely unpredictable. Nevertheless, with a long and rich experience in crop CBC, diverse authors have highlighted and assessed some of the requirements: fourteen chapters by 27 contributors in Gurr et al. (2004) provide an overview of advances in habitat manipulation techniques in pest management, and reviews by Rusch et al. (2010) and Orr and Fox (2012) show how CBC continues to progress.

*Dermanyssus gallinae*, the poultry red mite (PRM), is a bird-associated obligatory hematophagous mite of economic importance worldwide, particularly on egg-producing farms (Sparagano et al., 2014). CBC looks particularly promising against this pest because its life habits better match that of a micropredator than a typical parasite *sensu* Lafferty and Kuris (2002). Similar to bedbugs or adult female mosquitoes, PRM feeds on different host individuals successively and otherwise spends most of its life off the host. As it uses the hen legs to go and have a meal, to reduce the probability of getting crushed, PRM requires a quiescent bird host on which to feed. Therefore, its distribution at the farm level is concentrated within areas where hens are laying and/or resting, which restricts PRM to the farm building, whether any open area is available to hens or not. Consequently, PRM is fully integrated into the food webs occurring within the microhabitats of a building, and as a result, naturally occurring predatory arthropod communities in layer building microhabitats may play a role in suppressing PRM.

Development of biocontrol against this pest requires improved understanding of arthropod community ecology on layer farms. Arthropods are the taxonomic group most likely to contain natural enemies of PRM, including parasitoids and/or predatory insects and arachnids. Among arachnids, the mite order Mesostigmata is one of the most promising. In addition to a few hematophagous species (e.g., *Dermanyssus* spp.), the order includes a diversity of predatory mites, many of which feed on other mites. At least one of these predators, *Androlaelaps casalis* (Berlese, 1887) (Laelapidae), feeds on PRM, reducing local populations (Lesna et al., 2009, 2012). This species is currently authorized as a biocontrol agent for inoculation against exogenous mite populations in France (Annex 1 of the French ministerial order NOR: AGRG1502673A – https://www.legifrance.gouv.fr/eli/arrete/2015/2/26/AGRG1502673A/jo/texte), and some farmers feel that *A. casalis* releases may be helpful in suppressing PRM.

There exist very few extensive studies on poultry mite fauna. Axtell and Arends (1990) identified three species from three different families (Macrochelidae, Parasitidae and Uropodidae) as the primary predatory mites in poultry manure worldwide. Excluding hematophagous mesostigmatid mites (Dermanyssidae, Macronyssidae), no more than five non-hematophagous mesostigmatid species are recorded in single non-exhaustive studies worldwide. In the Philippines, three species of Macrochelidae, one species of Parasitidae (Gamasina) and one species of Uropodidae (Uropodina) occur in poultry manure (Rueda et al., 1990). On European poultry farms, one species of Blattisociidae, two of Melicharidae, one of Laelapidae (Gamasina) and one of Polyaspididae (Uropodina) have been reported (Lesna et al., 2009; Maurer et al., 1993). *Androlaelaps casalis* was another recurrent species in the European studies. Horn et al. (2016) recorded eight non-hematophagous mesostigmatid species from Brazilian farms in the framework of an extensive trap-based survey of different housing systems. By contrast, Brady (1970a, b), in an extensive substrate study on different poultry systems in the United Kingdom, recorded 30 non-hematophagous mesostigmatid species in the following predatory families: Macrochelidae, Parasitidae, Rhodacaridae, Phytoseiidae, Ascidae/Blattisoccidae, Digamasellidae, Laelapidae (Gamasina), and Urodynichidae (Uropodina). The latter studies were conducted with the goal of evaluating the reservoir potential for pathogenic microorganisms associated with manure acaro-fauna in poultry systems that differ strongly from those currently used in France, e.g., deep litter, a rearing method introduced into the UK in the early 1950s (not commonly in use anymore in commercial European layer farms). As a result, the full predatory guild of mesostigmatid communities living in the current European free-range layer farms remains poorly known. Additionally, the control potential of non-mite arthropods in European poultry farms requires further study, because almost all studies of these were conducted in the USA and focused on fly control.

To optimize potential suppression of PRM by natural predator communities, we must first understand poultry building ecology. In this pilot study we documented layer farm arthropod community composition, including environment and time effects, with a focus on mesostigmatid mites, because this group likely contains multiple species with suppressive potential against this pest mite.

To assess CBC potential of manure-dwelling arthropods/mites on layer farms, we need to establish whether arthropods that prey on other invertebrates are likely (1) to spillover from adjacent or nearby habitats into farm buildings and (2) establish themselves in buildings and (3) have a suppressive effect on the pest mite during a flock cycle. In the present study, the focus was on the first two axes (1 and 2). To explore them, using the perspective of the 2-scale framework highlighted by Begg et al. (2017), the following two questions were addressed: To what extent does the surrounding landscape play a role in structuring the manure-dwelling arthropod community, particularly the predatory guild (regional scale)? What is the influence of building-level actions (i.e. farming practices) on arthropod/mite communities (local scale)? The following hypotheses were tested: a) the structure of communities is influenced by mobile mites and insects spilling over from the outside according to both season and geographical unit (regional scale); because physical conditions inside the buildings are largely controlled, no significant change in community structure as a function of landscape would suggest that the phenology of natural enemies was primarily driven by internal conditions; b) the type of farm management and flock age (as correlated with the amount and quality of accumulated manure) will influence local community composition (local unit = building).

To test these hypotheses, we characterized the taxonomic composition of arthropod fauna in layer buildings with different farm management strategies (conventional with/without any open-air, organic, and Red Label) (local scale) located in two different French areas (regional scale). We developed a morpho-molecular approach to explore manure-dwelling arthropod communities. Lastly, because CBC requires that natural enemies spilling over from adjacent or nearby habitats at least temporarily establish in the target agro-habitat (axis 2 above), the sensitivity of two dominant mesostigmatid species to a common insecticide was also tested to complement the local-scale information and obtain insights into the potential persistence of native natural enemies and the possible effects of intensive farming on natural enemies.