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ERRONEOUS HOST IDENTIFICATION FRUSTRATES SYSTEMATICS AND DELAYS IMPLEMENTATION OF BIOLOGICAL CONTROL

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Bin F., Roversi P.F., van Lenteren J.C. – Erroneous host identification frustrates systematics and delays implementation of biological control.

Misidentifications of pests and their natural enemies and misinterpretations of pest-natural enemy associations have led to the failure of a number of biological control projects. In addition to misidentification, more complicated kinds of errors, such as mistakes in establishing host records of parasitoids, have resulted in inaccurate host-parasitoid lists of even well-known pest species. Here we discuss a particular problem of misinterpretation caused by complicated host-natural enemy habitats. Six examples are presented illustrating that mistakes in collection of host material can easily result in attribution of natural enemies to a wrong host species. To prevent such mistakes, it is advised that (1) extreme care should be taken when collecting host material in the field, (2) collected material should be partly dissected in order to check for potential contamination with non-host material, (3) supposedly new parasitoid-host associations inferred from specimens that emerged in the laboratory should be confirmed by field observations, (4) assignment of parasitoids to new hosts should only be done after consulting taxonomic specialists for the host and parasitoid.

KEY WORDS: False host records, parasitoid-host associations, gypsy moth, San Jose scale, oak processionary moth, winter moth, scarabid dung beetles

INTRODUCTION

Accurate identification of a target pest species and species of natural enemies proposed for use in biological control is a very critical aspect of each biological control programme (*e.g.* DE BACH, 1964; COCK *et al.*, 2010). Taxonomic mistakes made during the initial phase of a biological control programme can have long-lasting effects which delay the success of a project and can be very costly. Incorrect identification of a pest species can result in the search for natural enemies at the wrong location and the collection of natural enemy species that will not attack the pest. Misidentification of a natural enemy may lead to non-establishment of the biological control agent or low pest attack rates (*e.g.* GORDH, 1977).

There are several examples illustrating such mistakes. One case relates to the mass rearing and release of 300,000,000 *Trichogramma fasciatum* (Perkins) annually during a period of 20 years for the control of the sugar cane borer, *Diatraea saccharalis* (F.) on Barbados, where *Trichogramma minutum* Riley should have been used (GORDH, 1977). Another case deals with the release of the mass-produced, misidentified and ineffective parasitoid *Prospaltella fasciata* Malenotti for control of *Quadraspidiotus perniciosus* (Comstock) instead of the effective parasitoid *Prospaltella perniciososa* Tower during a 4-year period in Germany (ROSEN & DEBACH, 1973). A third example concerns the delay in obtaining control of California red scale, *Aonidiella aurantii* (Maskell), by parasitoids of the genus *Aphytis* Howard. Repeated misidentification of several species of *Aphytis* precluded establishment of the most promising species for over 50 years

(COMPÈRE, 1961). COMPÈRE (1969) summarized the *Aphytis* case as follows: “The history of (.. biological control of..) red scale is largely an account of contradictions and blunders, all directly owing to the failure of systematics, biologists, and collectors to identify correctly the insect with which they are working”. GORDH (1977) stated that misidentifications are inevitable because of the too small number of taxonomists working on natural enemies, the unreasonably large identification loads and the poor taxonomic foundation of many arthropod groups. This situation has become more troublesome during the past 30 years (*e.g.* COCK *et al.*, 2010).

In addition to misidentifications, other and even more complicated kinds of errors may occur. These concern serious mistakes in establishing host records of parasitoids. NOYES (1994) addressed the reliability of information about host-parasitoid associations in publications and demonstrated that published host-parasitoid lists of well-known species can be very inaccurate. This became evident when taxonomists carefully analysed such lists, found apparent mistakes and, to double check, studied and reared hosts and parasitoids. NOYES (1994) provided several convincing examples of false host records. His first example concerning two *Aleiodes* spp. (Braconidae) involved more than 50 wrong host records. Next, he presented examples of the parasitoids *Cotesia glomerata* (L.) (Braconidae) and *Trichogramma evanescens* Westwood (Trichogrammatidae), pointing at unrealistically long host lists. Finally, he mentioned that, according to the literature, many parasitoids were recorded from the host *Plutella xylostella* (L.) (Lepidoptera), but that after examination of this list only about 30% of the recorded para-

sitoids seemed correct. He gave the following reasons for these erroneous records: (1) mixed series of hosts, (2) mixed series of parasitoids and hyperparasitoids, (3) misidentifications of host and/or parasitoid due to inadequate or poor basic and applied taxonomy, (4) disregarding the opinion of taxonomists, (5) spelling mistakes of parasitoid or host names, and (6) misidentification resulting from inadequate material or inadequate information.

In this paper, we deal with a particular problem related to potential misinterpretation caused by complicated host-natural enemy habitats. This problem concerns Noyes's first reason for erroneous records: mixed series of hosts (Fig. 1). Careful and time-consuming field work is often needed to make corrections of such mistakes possible. This type of mistake concerning host records not only leads to confusing situations in taxonomy, but can

also result in delays in obtaining biological control of pests because the wrong species of parasitoids were released.

Although this issue has been highlighted for some time, scientific papers have recently been published that establish new associations that we believe require further investigation. An example is the description of a new species of the genus *Telenomus* Haliday, which the authors referred to as obtained from egg masses of *Thaumetopoea pityocampa* (Dennis et Schifferrmüller) collected in Spain in forests of *Pinus halepensis* Mill. (SELFA *et al.*, 2009). Communities of egg parasitoids of the pine processionary moth and other species of the genus *Thaumetopoea* have been investigated in several studies in different environments of the Mediterranean Basin, but in no case has *Telenomus* or other scelionids been obtained (TIBERI &

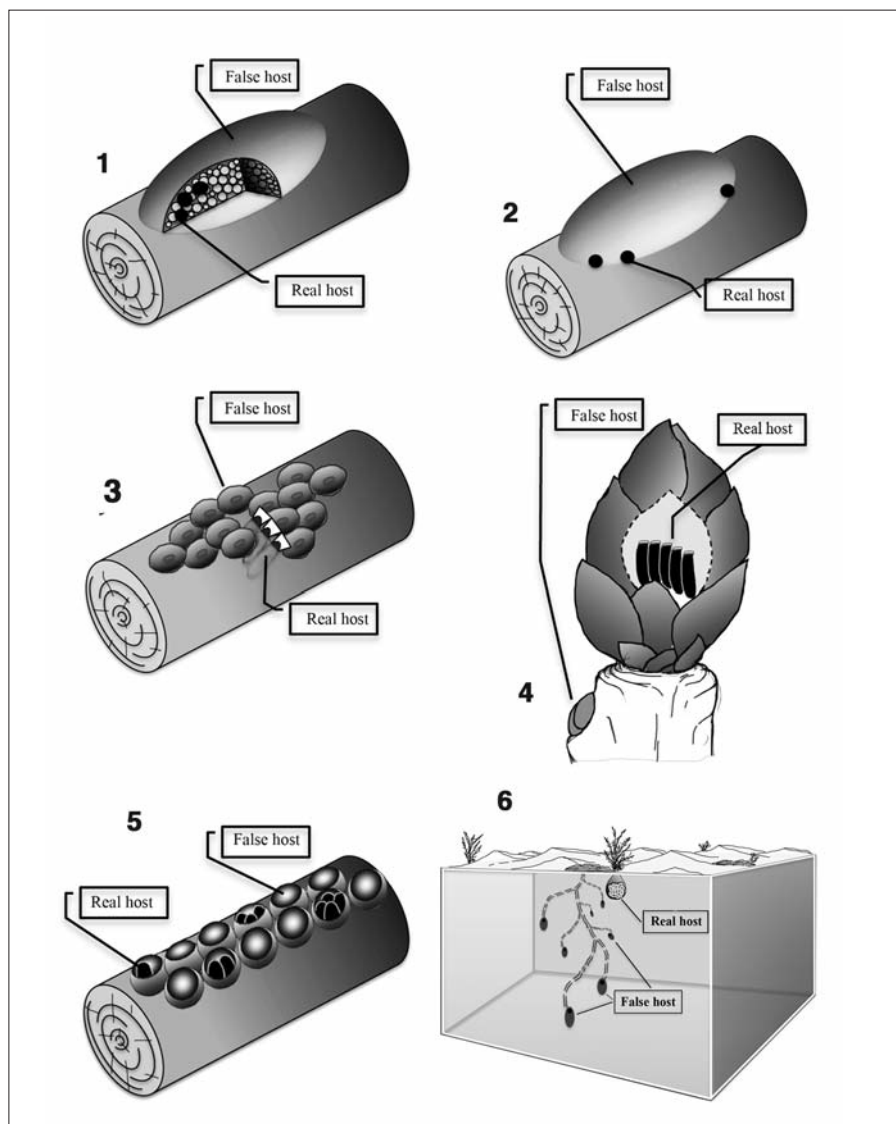


Fig. 1 – Schematic representation of the position of the real host in relation to that of the false host: (1) Case 1: real host eggs are mixed up with false host eggs during the collection of field material, (2) Case 2: real host eggs are laid on the egg mass of the false host, (3) Case 3: real host eggs are embedded in the plant and obscured by the false host, (4) Case 4: real host eggs are embedded in the plant and not visible externally, (5) Case 5: eggs of the real host are hidden inside the empty egg shell of the false host, and (6) Case 6: eggs of the real host occur in the soil near those of false hosts.

ROVERSI, 1987; BELLIN *et al.*, 1990; KITZ & SCHMIDT, 1993; TSANKOV *et al.*, 1995; SCHMIDT *et al.*, 1997; LOPEZ-SEBASTIAN *et al.*, 2003; MOHAMED *et al.*, 2006). Hence the report by SELFA *et al.* (2009) should be carefully controlled to verify the presence of eggs of other Lepidoptera inside or near the *T. pityocampa* egg masses.

We will address several cases exemplifying the danger of false host records, and we will show that careful in situ observations of natural enemy behaviour and development are interesting topics essential for progress in understanding parasitoid-host relationships, as well as for developing reliable guidance for biological control.

CASES ILLUSTRATING THE RISK OF MISINTERPRETING PARASITOID HOST ASSOCIATIONS

EGGS OF THE REAL HOST ARE MIXED UP WITH THOSE OF THE FALSE HOST DURING EGG MASS COLLECTION: GYPSY MOTH AND *GRYON* SPP. AND *TELENOMUS* SPP.

Many natural enemies of the gypsy moth, *Lymantria dispar* (L.), have been identified during the past century and several of them have been introduced into the USA for control of this pest (WASHBURN, 1984). Among the natural enemies found in association with the gypsy moth are various species of egg parasitoids (e.g. ANDERSON, 1976). However, BIN (1980a) questioned several of the host records after evaluating the information on 10 species of scelionids (genera *Gryon* Haliday and *Telenomus* Haliday) supposedly reared from gypsy moth eggs and after examining host records of *Telenomus phalaenarum* (Nees) from material collected in Morocco and Algeria (DE LEPINEY, 1927). HÉRARD (1979) and HÉRARD & FRAVAL (1980) also expressed doubt as to the host record of some *Gryon* and *Telenomus* spp. found together with gypsy moth eggs, since they either failed to develop on gypsy moth eggs or they were suspected of having emerged from eggs of another host present on or close to the egg masses (HÉRARD *et al.*, 1979). Moreover, scelionids which are undoubtedly parasitoids of other hosts such as spiders have been found among material supposedly reared from gypsy moth egg masses and received for identification (BIN, personal observation). An example of a probably misidentified host relationship concerns *Gryon hungaricus* (Szabó), which was recorded from the gypsy moth in Morocco and from *Orgyia trigotephras* Boisduval in Italy (MINEO, 1979). However, no further specimen emerged from several thousand gypsy moth eggs collected later in Italy, and thus the record from the gypsy moth was considered fortuitous (MINEO, 1980). Nevertheless, there might be another explanation why this parasitoid was found in association with gypsy moth egg masses, in that *G. hungaricus* could have developed in eggs of other hosts, as suggested by HÉRARD & FRAVAL (1980). Other examples of potential misinterpretation of host records concern *Telenomus embolicus* Kozlov, *Telenomus longistriatus* Kozlov and *Telenomus lymantriae* Kozlov, because they have only been reported once and are based on only a few specimens (BIN, 1980a).

Therefore, after studying parasitoids which emerged from massive collections of gypsy moth eggs, an inexperienced taxonomist might conclude that the above-mentioned species of egg parasitoids are rare parasitoids of gypsy moth eggs instead of eggs of other hosts (Fig. I, 1).

EGGS OF THE REAL HOST ARE LAID ON THE EGG MASS OF THE FALSE HOST: GYPSY MOTH AND *XENOMERUS*

During a study of gypsy moth egg parasitoids in central Italy in the 1970s (BIN, 1980b), egg masses were collected and parasitoids were sampled with Malaise traps in oak woods. Among others, two species of the genus *Xenomerus* Walker (*X. ergenna* Walker and *X. canariensis* Huggert) were found. Nothing is known about these species, even though they were described in the 1830s. When BIN (1980b) studied the egg masses of the gypsy moth, he discovered curious objects on the egg masses, isolated them and observed emergence of two females of *X. ergenna*. He concluded that the curious objects were egg cases, possibly of the genus *Dromius* Bonelli (Coleoptera, Carabidae). As the adults of *Dromius* spp. are known to be tree and shrub dwellers (THIELE, 1977), he inspected potential hiding places of *Dromius* spp. under bark and mosses of the same oak trees where the gypsy moth egg masses were collected and found adults of *D. meridionalis* Dejean and *D. quadrimaculatus* (L.). Laboratory rearing of the species failed, so it was impossible to determine if the egg cases found on the gypsy moth egg masses belonged to *Dromius* spp. However, this supposed host record (i.e. *Dromius* spp. as host for *Xenomerus* spp.) might explain some "rare" parasitoid species reared from gypsy moth egg masses.

This case shows that careful collection and rearing of host material is important to prevent the listing of wrong host records (Fig. I, 2).

EGGS OF THE REAL HOST ARE EMBEDDED IN THE PLANT AND OBSCURED BY THE FALSE HOST: SAN JOSE SCALE AND *TELENOMUS*

SOYKA (1942) described two new species of egg parasitoids said to be reared from *Aspidiotus perniciosus* Comstock (San Jose scale) found on apple branches: *Microphanurus fulmeki* Soyka and *Neotelenomus perniciosi* Soyka. The author mentioned that he checked the literature of the genera *Microphanurus* Kieffer and *Neotelenomus* Dodd and found no egg parasitoids listed which were said to attack *Aspidiotus*. Bin examined the original material (received from the museum of Berlin-Dahlem) which SOYKA (1942) had used for the description of the species and concluded they were all *Telenomus* ("types seen") and not *Microphanurus* or *Neotelenomus*. It is well known that *Telenomus* species have never been recorded from any scale insect, which explains why SOYKA (1942) could not find any species of this or related genera reared from *Aspidiotus* scales. The *Telenomus* parasitoids must have emerged from another host living on apple branches, most probably from mirids which lay their eggs embedded in plant tissue.

This case demonstrates that, in addition to good taxonomic knowledge, careful isolation of host material is necessary to avoid the emergence of parasitoids which have not developed in the target host (Fig. I, 3).

EGGS OF THE REAL HOST ARE EMBEDDED IN THE PLANT AND NOT VISIBLE EXTERNALLY: *TORTRIX VIRIDANA* AND *CHAETOSTRICHIA WALKERI*

Tortrix viridana (L.) is one of the most important defoliators on *Quercus* spp. in the western Palaearctic region.

Eggs of this pest are laid in pairs and are covered with scales and debris on young oak twigs. The zoophytophagous mirid *Calocoris quadripunctatus* (Villers) preys on eggs of *T. viridana* and lays its eggs concealed in dead oak buds between the external bud scales. At this location, the mirid eggs are attacked by two species of egg parasitoids: *Chaetostricha walkeri* (Förster) (Hymenoptera, Trichogrammatidae) and a *Telenomus* sp. (Hymenoptera, Scelionidae) (CONTI *et al.*, 1997; CONTI *et al.*, 2000). In previous studies, *C. walkeri* has been erroneously reported to be obtained from eggs of *T. viridana* (MARTINEK, 1963), from the coccid *Leucaspis pini* Hartig. (NIKOL'SKAYA, 1952), or from unknown hosts, supposedly xylophagous larvae (SILVESTRI 1917 citing Förster) or heteropteran eggs embedded in wood (SILVESTRI, 1917). The eggs of *C. quadripunctatus*, the true host, were evidently overlooked because they were not visible externally.

This case also shows that good taxonomic knowledge and careful isolation of host material are necessary to avoid the emergence of parasitoids which have not developed in the target host (Fig. I,4).

EGGS OF THE REAL HOST ARE HIDDEN INSIDE THE EMPTY EGG SHELL OF THE FALSE HOST: OAK PROCESSIONARY MOTH AND WINTER MOTH, *TRICHOGRAMMA* SPP. AND *TELENOMUS MINUTUS*

In temperate forest ecosystems, the abundance of foliage-feeding caterpillars can change dramatically from generation to generation, sometimes showing more than 10,000 fold changes in density (BALTENSWEILER & FISCHLIN, 1988; BERRYMAN, 1996; ROVERSI & BIN, 2000). Egg parasitoids can play an important role in the population dynamics of these forest defoliators (ROVERSI, 2002). In European oak forests, the oak processionary moth *Thaumetopoea processionea* (L.) is an important pest, mainly because it causes serious irritation to the human skin and eyes (*e.g.* GOTTSCHLING & MEYER, 2006; EFSA, 2009; ROVERSI *et al.*, 2010) and it also damages oak trees (THOMAS *et al.*, 2002).

When searching for egg parasitoids of the oak processionary moth, one may encounter the following complicated situation. Females of *T. processionea* lay their eggs in a single-layered cluster covered by scales during late summer-early winter (BIN & TIBERI, 1983). These eggs overwinter until the bud burst of the oak tree, when caterpillars emerge from the eggs. The egg shells of *T. processionea* may remain for 1-3 years on branches and can be used by other insects, particularly by other lepidopterans from up to five different families. Females of these other lepidopteran species lay isolated or small groups of eggs in the empty egg shells. We found that females of the winter moth (*Operophtera brumata* L.) most commonly used the old egg shells of the oak processionary moth to lay their eggs (ROVERSI & BIN, 2000; Fig. II). In 1998, a sample of 350 old *T. processionea* egg shells was studied and 2% contained winter moth eggs. In 1999, 8% of 569 egg shells contained winter moth eggs. Up to four winter moth eggs could be found in an old egg shell, but the majority of egg shells contained one egg. Only a small percentage of winter moth eggs are laid in old oak processionary moth egg shells, the majority being laid in crevices in the oak bark. Winter moth eggs, whether laid in crevices or in old *T. processionea* egg shells, are often parasitized by *Trichogramma* spp. and *Telenomus minutus* Ratzeburg.



Fig. II – An egg shell of the oak processionary moth (*Thaumetopoea processionea*) containing 7 egg shells of another lepidopteran.

Now imagine the following scenario: in an effort to find egg parasitoids of the oak processionary moth, large numbers of eggs of this pest are collected, put in containers and kept in the laboratory until either moth larvae or parasitoids have emerged. *Trichogramma* and *Telenomus* spp. that emerge from material collected in this way can be wrongly classified as parasitoids of *T. processionea*.

Therefore, since the use of old egg shells of the oak processionary moth is poorly known (ROVERSI & BIN, 2000), it is not unrealistic to expect that such egg shells with other host eggs will be collected and lead to the conclusion that oak processionary moth eggs are parasitized by natural enemies of another host (Fig. I, 5).

EGGS OF THE REAL HOST OCCUR IN THE SOIL NEAR THOSE OF FALSE HOSTS: FIRST HOST RECORD EVER OF *ENCYRTOSCELIO*

Terrestrial scarabid dung beetles dig holes in the soil, fill the hole with animal dung and lay an egg in the dung. Dr. J.P. Lumaret, a French taxonomist and biologist of dung beetles, once found an adult apterous microhymenopteran close to the egg of a dung beetle and sent both the dung beetle egg and the adult microhymenopteran to F. Bin for identification (BIN, 1979). Bin responded that this host record seemed impossible and advised Lumaret to carefully collect new material. More dung beetle eggs were collected, but at the same time Lumaret also found egg masses of heteropteran cydnids. Adult cydnids, like dung beetles, hide their eggs deeply in the sand of dunes. This time Lumaret did not rear any egg parasitoids from the dung beetle eggs, but did obtain parasitoids from the cydnid eggs, which were initially identified as *Encyrtoscelio apterus* (Stelényi) (BIN, 1979). Later they were described as a new species, *E. cydni* Caleca (CALECA & BIN, 1995), egg parasitoids of *Cydnus aterrimus* (Forster), a cydnid species living in close association with *Euphorbia* spp. It is known that parasitoids of the genus *Encyrtoscelio* Dodd are able to locate the small egg masses in the sand (BIN, 1979) and based on the cur-

rent knowledge of the genus *Encyrtoscelio* it can be concluded that there is a close relationship of these parasitoids with their cydnid host eggs (CALECA & BIN, 1995).

This case shows that careful collection of material and proof that the parasitoids emerged from the supposed host material is essential to prevent publication of false host records (Fig. I,6).

DISCUSSION

The six cases described in this paper clearly show that mistakes in collection of host material can easily result in attribution of natural enemies to a wrong host species. We are convinced that the presented cases form only the tip of the iceberg of false host records and this only relates to the first reason for erroneous host records listed by NOYES (1994). General conclusions to be drawn from the above cases are that (1) extreme care should be taken when collecting host material in the field, (2) collected material should be partly dissected in order to check for potential contamination with non-host material, (3) supposedly new parasitoid-host associations inferred from specimens that emerged in the laboratory should be confirmed by field observations, (4) assignment of parasitoids to new hosts should only be done after consulting taxonomic specialists for the host and parasitoid.

The misinterpretations listed in this paper underline the importance of a statement made by FERRIÈRE (1962): "Ma conclusion sera, au moins pour les Hyménoptères parasites, qu'il est actuellement plus important de trouver l'hôte ou les hôtes d'une espèce déjà connue, que de décrire une nouvelle espèce sur du matériel capturé au filet, surtout, sauf exceptions, si l'espèce est basée sur un ou deux exemplaires." (in summary: it is more important to find the host or hosts of an already known (parasitoid) species, than to describe a new species...").

The authors of this paper would like to be informed of any other cases of misinterpretation of host records in order to obtain an idea of how often complicated host-parasitoid relationships occur, as well as to be able to provide an overview of this phenomenon for researchers in biological control.

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