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Rapid Communication

Going overseas: from island to continent colonization in the Mediterranean snakefly *Fibla maclachlani* (Albarda, 1891)

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Abstract

The presence of *Fibla maclachlani* (Albarda, 1891) (Raphidioptera, Inocelliidae) has been recorded in Tuscany (central Italy) since 2005 according to information derived from both a biodiversity survey project and citizen science activities. The species, whose natural distribution includes the three main islands of central Mediterranean—Corsica, Sardinia, and Sicily—was most likely introduced into Tuscany through the raw cork trade from Sardinia. Further molecular comparative analyses are needed to confirm this hypothesis. This would be the first case of human-mediated jump dispersal in this family and a rare example of upstream colonization from island to continent. Two isolated records of *F. maclachlani*, an old (1905) and a very recent one (2018), are also reported from Calabria. The presence of *F. maclachlani* in Calabria remains unclear, the most reliable hypotheses are either the natural presence of the species at low population density or its introduction from Sicily at some point. The non-native populations of *F. maclachlani* currently coexist in the Italian peninsula in sympatry with the native inocelliid *Parainocellia bicolor* (A. Costa, 1855), a condition otherwise unknown among European species of this family. Future interactions between the two species are unpredictable.

Key words: Insecta, Raphidioptera, Inocelliidae, upstream colonization, Sardinia, Tuscany, Aspromonte

Introduction

The Raphidioptera constitutes the superorder Neuropterida together with the orders Megaloptera, and Neuroptera. It is the least diverse order among the Holometabola, i.e. insects characterized by complete metamorphosis. Winged adults have an elongate, very mobile prothorax, hence the common name of "snakeflies". Females also possess a long ovipositor. Predaceous larvae are terrestrial, and live in bark or in soil detritus (Aspöck and Aspöck 2009).

The Inocelliidae is one of the two extant families of the order Raphidioptera. It comprises merely 42 species arranged into seven genera (Engel et al. 2018). The main differences from the other family Raphidiidae

are the lack of ocelli (from which their Latin name derives), a less elongate and mobile prothorax, aphagous adults (adult Raphidiidae are predators), and larvae living only in bark (Pantaleoni 2007; Aspöck et al. 2012). Some Inocelliidae species, e. g. *Parainocellia bicolor* (A. Costa, 1855) and *Fibla maclachlani* (Albarda, 1891), are able to colonize, for instance, fruit crops, nut crops and, in particular, vineyards (Pantaleoni 1990, 2007; Pantaleoni and Alma 2001).

In both Raphidiidae and Inocelliidae families, individual specimens can complete their cycle in one year, even though a larval period of two years or up to a maximum of seven years in captivity, is much more common. In any case, larval resistance to starvation is very high (Aspöck 2002; Aspöck et al. 2012; Pantaleoni, *unpublished data*).

Snakeflies are present only in the northern hemisphere, mainly between 30° and 60°N, in Euro-Asia and in southwestern parts of North America (Aspöck et al. 1991; Aspöck 1998). The majority of the species have very small ranges, geographically limited even to a single mountainous massif, whereas only three species have a vast Eurosibiric distribution from central Europe to the Asian Pacific coast (Aspöck 2002).

The well-known Euro-Mediterranean species of the family Inocelliidae have the distinction of all living in allopatry. Their geographical ranges overlap very slightly only along those borders that are in contact. The genus *Fibla* is present with four species in the Iberian Peninsula, Maghreb (from Morocco to Tunisia), the three islands of Corsica, Sardinia and Sicily, and, with a different subgenus, the island of Crete. The Italian, Balkan and Anatolian peninsulas each host a species of the genus *Parainocellia*. Lastly, the single European species of *Inocellia* lives in central Europe, but its geographical distribution reaches the Pacific coast of China passing through the central Asia (Aspöck et al. 1980, 1991).

Fibla maclachlani, which lives in Corsica, Sardinia and Sicily, has been found in Maremma, Tuscany (central Italy), since 2005 and the species seems to be expanding. A single record, attributable to this species, has recently been reported also from Aspromonte, Calabria (southern Italy). This short-range expansion is of particular interest since it would be the first case of an Inocelliidae species and a rare example of upstream colonization, from island to continent.

Methods

Data collection

The data come from the following sources: the CONECOFOR project; the citizen-science BioBlitz events; some social network sites of entomological or naturalistic content. An old record also derives from the literature.

In the context of the CONECOFOR project, a biodiversity survey was started in 2003/2004. Twelve forest plots (2500 m^2) were sampled by Malaise,

window and pitfall traps. The Neuropterida collected in 2005 and 2006 in all plots were studied by one of the authors (AL). The plot named TOS2, located in Cala Violina, Grosseto, Tuscany, is representative of a coastal holm oak (*Quercus ilex*) wood on sandstone (dry climate with 500–650 mm annual rainfall) (Petriccione and Pompei 2002). Surveying began at this plot in June 2004 (Mason et al. 2006).

The BioBlitz events take place worldwide (Lundmark 2003) and, in Tuscany, they have been organized by the Maremma Natural History Museum since 2013 (Sforzi et al. 2013). The Neuropterida collected during BioBlitz events occurred in Tuscany between 2014 and 2018 were examined by one of the authors (Letardi 2018). Two BioBlitzes were organized in 2013 and 2014 at the "Oasi di San Felice", a WWF coastal private reserve, characterized by stone (*Pinus pinea*) and maritime (*P. pinaster*) pine wood and mature sandy dunes (Sforzi 2017).

Specialized Italian forums, Facebook groups, and other online tools for sharing biodiversity watching were constantly monitored in the last decade by two authors (RAP and AL) in order to collect data on Neuropterida. When photos of *F. maclachlani* were found, the photographer was contacted personally and a confirmation and further details on the data were requested.

Identification

All known species of the family Inocelliidae are well differentiated and characterized. An unambiguous identification is possible by examining the male or, with more difficulty, female genitalia. Genera can also be discriminated on the basis of external morphology (eidonomic characters) (Aspöck et al. 2012). Keys and very detailed illustrations are available for all the Euro-Mediterranean species (Aspöck et al. 1980, 1991).

Captured specimens were examined by the authors and accurately identified. For a few specimens there are only photos (Supplementary material Table S1). From a photo, an unambiguous discrimination between the genera *Fibla* and *Parainocellia* is possible both from the external features (Figure 1) and the difference in the venation (Figure 2).

Results

Tuscany

Records of *F. maclachlani* regarding Tuscany are detailed in Table S1 and mapped in Figure 3. The identification of all the collected specimens was confirmed by the examination of genitalia. The few records based only on photos are not verified at species level, though it is very unlikely that they refer to other species.

Figure 1. Comparison between *Fibla maclachlani* (left) and *Parainocellia bicolor* (right) as adult female (up) and almost mature larva (down). The main external discriminant features in adults are: *F. maclachlani,* head and prothorax with a typical two-colour pattern, caudal margin of the majority of the abdominal urites with two white spots more (female) or less (male) widely separated, general appearance deep brown but not black; *P. bicolor* head and prothorax almost entirely dark without a clear pattern, caudal margin of the majority of the abdominal urites with one central elongated white spot, general appearance blackish or black. The discrimination of the larvae is harder due the dramatic changes in the physical appearance related to the specimen size. However, in *F. maclachlani* the general appearance is paler and less contrasted with respect to *P. bicolor*. Moreover, the pattern of spots in the abdomen resembles that of the respective adults. [Photo courtesy of: Giuseppe Miceli, Florence (*F. maclachlani* female, record #2 of Table S1), Pietro Niolu, Sassari (*F. maclachlani* larva, Villanova Monteleone, N-Sardinia, December 2007), and Luigi Lenzini, Roma (*P. bicolor* adult and larva, Santa Severa, Latium, April–May 2011).]

With one exception, all records were located in the central part of Maremma between Piombino (an important commercial port) and the city of Grosseto. Only the most recent record was from Sesto Fiorentino, near Florence, further north than the others.

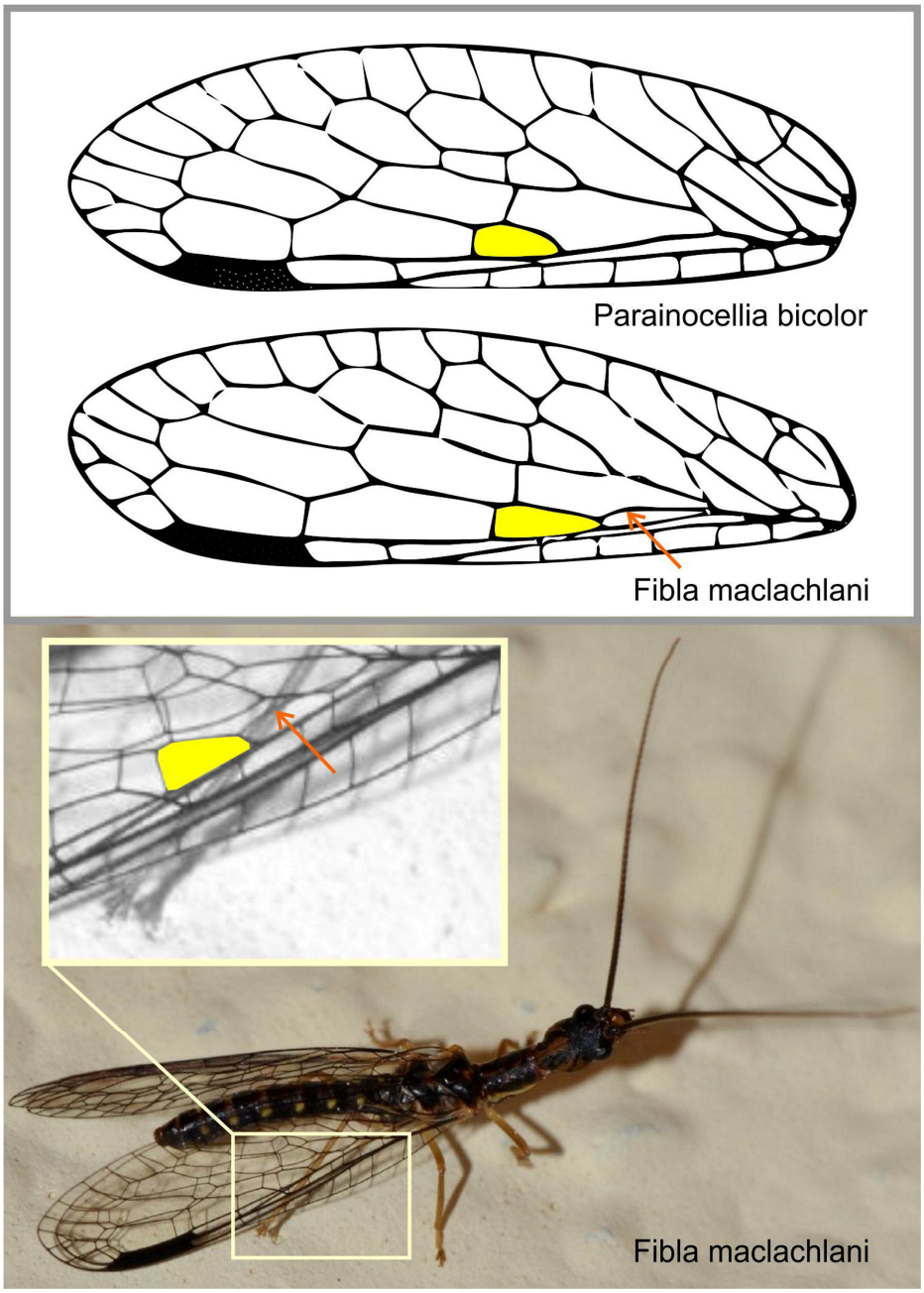

Figure 2. Difference in the wing venation that differentiates the genera *Fibla* from *Parainocellia*. Top, the hind wing of the two genera in natural resting position. The yellow area highlights the basal cell between Radius anterior and Radius posterior. The red arrow points to the media anterior (according to the definition of Aspöck et al. 1980, 1991) present in *Fibla*, but absent in *Parainocellia*. Bottom, the case study of record #3 (Table S1), a male of *Fibla*, presumably *F. maclachlani*, is clearly identifiable by the external features and the presence of the media anterior. [Photo courtesy of Bruno Parisotto, Grosseto.]

Calabria

The only recent record of *Fibla* from Aspromonte is detailed in Table S1 #8. Again, the identification at a species level cannot be verified, though the hypothesis that the collected specimen belongs to a different species is unlikely.

An old record from Aspromonte was reported by Aspöck and Aspöck (1966). A female, labelled "Antonimina, Paganetti", is conserved in the

Figure 3. Sites in which *Fibla maclachlani* was recorded as non-native. The native distribution (Corsica, Sardinia, and Sicily) is highlighted in red. Reference numbers refer to Table S1.

Naturhistorisches Museum in Vienna. Antonimina is a town near Aspromonte (38.27408N; 16.14766E), and Paganetti refers to Gustav Paganetti-Hummler (1871–1949), entomologist and scientific writer (Franz 1977). The capture was probably made in April–May 1905 (Paganetti-Hummler 1910).

Discussion

Inocelliidae have a weak dispersal power. Indeed, they are poor fliers, particularly the females. In these insects, which do not feed as adults, the well-fed larvae produce voluminous (giant) females which are very fecund, because of endogenous reserves acquired through larval feeding, and are yet practically unable to fly (Pantaleoni 1990). On the other hand, they have many ecological features favourable to an anthropogenic dispersal, above all the exceptional resistance to starvation shown by the larvae. Ornamental potted plants, firewood (with bark), and raw cork (widely produced in Sardinia) could host larvae of Inocelliidae for weeks, if not months, becoming the ideal means of dispersal.

The colonization of Tuscany by *F. maclachlani* presents very few doubts about its anthropogenic origin. All the records, except for the most recent one, come from a limited area near Piombino, a very important port for the transport of goods to and from Sardinia. The species has been continuously recorded in that area during the last 15 years; its range is expanding apparently very slowly. The last record near Florence could derive from a human-mediated jump dispersal.

The only alternative hypothesis could be a natural presence of the species along the Tuscan coast, in front of the Tuscan Archipelago, a situation biogeographically very improbable but not impossible. In fact, on the one hand, the species could have been restricted to the most suitable habitats in Maremma and have begun its expansion recently. On the other hand, the presence of the species could have passed unnoticed in the past when the interest about this order and, above all, "citizen science" activities were absent or insignificant. However, these scenarios are very weak, as the presence in such a small area is incompatible with the wide ecological tolerance of the species.

Furthermore, there is another well-known case that supports the hypothesis of anthropogenic introduction in a much more convincing way. In fact, *Carabus (Macrothorax) morbillosus* Fabricius, 1792, was found for the first time near Piombino in 1973. Until 1985, the presence of this noticeable species was limited to a close-by area (between Follonica and Scarlino) (Casale et al. 1989; Bastianini 1991), which coincides perfectly with the first Tuscan record of *F. maclachlani* (#1, Table S1). In 1986, *C. morbillosus* was found in Grosseto (Bastianini 1991), and today it is also established in Latium, near Ostia Antica (Lenzini 2013; Gigli 2015; Jordà 2018). In this case, the lack of older records is not attributable to a possible lack of observations, as the genus *Carabus* is one of the most searched for taxa for collection by both amateur and professional entomologists. The means of introduction was identified in the trade of raw cork from Sardinia to the cork factories established in Follonica since the beginning of the last century (Casale et al. 1989). Therefore, the colonization in Tuscany of *F. maclachlani* and *C. morbillosus* appears to be very similar.

The records from Aspromonte are more difficult to interpret. A natural ancient colonization would seem the most reasonable hypothesis, except that Aspöck et al. (1991: I, 484) report no findings by intensive search of larvae (the most specialized and effective way of sampling). Therefore, *F. maclachlani* could be established in Aspromonte at a very small population level (natural presence), or with a spotted and dispersed distribution (failure to invade after naturalization). Alternatively, the records are due to single spread-out specimens or to a temporary colonization from nearby Sicily (failure to naturalize).

The only other documented case of human-mediated dispersal in Raphidioptera is that of the Raphidiidae *Raphidia mediterranea* Aspöck, Aspöck et Rausch, 1977. This species is apparently expanding its geographical range north-west from the Peloponnese, colonizing on the one side the Italian Peninsula and on the other side the Balkans, until reaching Upper Austria (Aspöck et al. 2017: 126, Fig. 5). The anthropogenic dispersal of *R. mediterranea* was once controversial (Pantaleoni 2005), but recent data seem to confirm at least one case of range expansion by a human-mediated jump.

There has been one attempt to introduce a Raphidioptera species for beneficial purposes (Anonymous 1890; Chittenden 1892): an unknown species of "*Raphidia*" (currently classified as *Agulla* or *Alena*) was collected in California by Albert Koebele, the local field agent of the Division of Entomology, US Department of Agriculture, and forwarded, in two shipments, to Mr. Wight in New Zealand in order to introduce a natural enemy of the codling moth. The specimens arrived alive but the introductions failed.

According to the currently available information, the colonization of Tuscany by *F. maclachlani* is a rare example of overseas jump dispersal in Raphidioptera and, above all, a case of upstream colonization from island to continent (Bellemain and Ricklefs 2008). An important role in the success of the invasion was played by the number and the size of release events (propagule pressure) that often reflect the extent of commercial trade between two (or more) countries (Lockwood et al. 2005). In our case, it is very improbable that aphagous and short-lived *Fibla* adults can act as propagules. Colonization was most likely due to larvae, which have a very long lifespan and a strong resistance to starvation. If a sufficient number of *Fibla* larvae were released, it is reasonable to expect that they were able to produce enough adults that mated and laid eggs. Consequently, the population became self-sustaining, established, and was finally able to expand its range. Comparative genetic analyses among the populations of Sardinia, Corsica, Sicily, and Tuscany are needed in order to clarify the origin of non-native populations and put forward hypotheses on the mode of dispersal. However, the cork trade from Sardinia to Tuscany, suggested also for the introduction of *C. morbillosus*, seems to be the most likely hypothesis on how *F. maclachlani* was introduced in the new area. In fact, the cork trade from Sardinia to Tuscany has been extensive for many years, with a frequency that could have ensured the release of a sufficient number of larvae.

The non-native population of *F. maclachlani* currently cohabits sympatrically with *P. bicolor*, the Inocelliidae species living in the Italian Peninsula. This condition is still unknown among European species of this family. Both species colonize a wide range of habitats largely, if not

entirely, overlapping. The size and life-cycle of both species appear very similar to each other, even though *Fibla* could be more thermophilous. Consequently, also the ecological niches do not seem to be well separated. In conclusion, the interactions that will develop are totally unpredictable.

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Supplementary material

The following supplementary material is available for this article:

Table S1. *Fibla maclachlani* records from Tuscany and Calabria.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2019/Supplements/BIR_2019_Pantaleoni_etal_Table_S1.xlsx