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Describtion of Lycaenidae Butterflies

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Abstract

The Lycaenidae is a family comprising several thousand species, the majority of which are small in size and with a rapid flight. Many are brilliantly coloured, and this is often the result of interference effects caused by the microstructure of the wings. Eyes may be smooth or hairy, often with a border of dense white scales. Labial palps usually protrude forward, or are slightly ascending. Antennae are half the length of the forewing or slightly shorter, with a variable but usually long club. All legs are fully functional in both sexes, although the forelegs of the male are less well developed, and smaller, than in the female. All legs have a pair of claws, with the exception of the male foreleg which has a single claw. In some genera there are spines on the tibia. The number of veins on the forewing is generally reduced to 11 or even 10 with vein 8 and possibly vein 9 absent. The cell is narrow when compared with other families. The undersides of the wings typically differ greatly from the upper sides, often consisting of a pattern of spots. Sexual dimorphism is usually well-defined. In some genera there is a short tail at vein 2 of the hind wing. Androconial scales are usually present on upper side of male forewing.

Keywords: Honey gland; Retractable Neck; Maculinea Arion; Myrmecophily

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Introduction

The Lycaenidae Family of butterflies are the second largest family of butterflies in the world consisting of over 6000 species. Members of this family are also called the 'gossamer winged butterflies'. They represent around 40% of all known butterfly species. Adults are small, usually under 5 centimetres in length. They are brightly coloured, sometimes with a metallic gloss. The males forelegs are reduced in size and lack claws. Larvae are often flattened rather than cylinder shaped, with glands that can produce secretions that attract and subdue ants. Their cuticles tend to be thickened. Some larva is capable of producing vibrations and low sounds that are transmitted through the plants. They use these sounds to communicate with ants. Lycaenids are diverse in their food habits and apart from phytophagy, some of them are entomophagous (the practice of eating insects as food) feeding on aphids and ant larvae. Some of them are also associated with ants and are fed by ants. Not all Lycaenidae butterflies need ants, but about 75% of species associate with them. In some species, larvae are attended and protected by ants while feeding on the host plant and the ants receive sugar-rich honeydew from them throughout the larval life. Exhibition of myrmecophily by the larval instars is the significant character of Butterflies of Family: Lycaenidae. The larvae of many lycaenid butterflies (Lepidoptera: Lycaenidae) are tended by ants that protect them from natural enemies in return for sugar-rich secretions that the larvae produce to attract and retain their ant guards. Mathew, D. Trager and Jaret C. Danies (2009) investigated the relationship between larvae of the endangered Miami blue butterfly (*Cyclargus thomasi bethunebakeri* Comstock & Huntington) and potentially mutualistic ants. Mathew, D. Trager and Jaret C. Danies (2009) observed 10 ant species interacting with Miami blue larvae in the field, and raised larvae successfully in captivity with 3 of these and 6 other ant species that are not known to tend larvae in the wild. In an experimental assessment of ant effects on larval performance, we found no differences in age at pupation, pupal mass, length of pupation, total time as an immature or ratio of time as a larva to time as a pupa among larvae raised with *Camponotus floridanus* Buckley, *Linepithema humile* Mayr, or in a no-ant control. Larvae raised with *C. floridanus* were significantly more likely to pupate in the ant harborage than larvae in the other treatments. Mathew, D. Trager and Jaret C. Danies (2009) did not observed ants behaving antagonistically toward Miami blue larvae in field, laboratory, or experimental conditions; even ant species previously identified as potential predators tended larvae. This report demonstrate that Miami blue larvae can elicit typical tending behaviors across diverse ant taxa and that ant tending does not substantially alter larval development, findings that may have implications for conservation and population restoration of the Miami blue butterfly. Lycaenidae is the second-largest family of butterflies (behind Nymphalidae, brush-footed butterflies), with over 6,000 species worldwide, whose members are also called gossamer-winged butterflies. They constitute about 30% of the known butterfly species.

Myrmecophily is the term applied to positive interspecies associations between ants and a variety of other organisms such as plants, other arthropods, and fungi. Myrmecophily refers to mutualistic associations with ants, though in its more general use the term may also refer to commensal or even parasitic interactions. The term *myrmecophile* is used mainly for animals that associate with ants. There are an estimated 10,000 species of ants (Formicidae), with a higher diversity in the tropics (Holldobler and Wilson,1990). In most terrestrial ecosystems ants are ecologically and numerically dominant, being the main invertebrate predators. As a result, ants play a key role in controlling arthropod richness, abundance, and community structure (Fiedler, *et al*, 1996). There is evidence that the evolution of myrmecophilous interactions has contributed to the abundance and ecological success of ants (Holldobler and

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Wilson,1994), by ensuring a dependable and energy-rich food supply and thus providing a competitive advantage for ants over other invertebrate predators (Bluthgen, *et al*, 2004). Most myrmecophilous associations are opportunistic, unspecialized, and facultative (meaning both species are capable of surviving without the interaction), though obligate mutualisms (those in which one or both species are dependent on the interaction for survival) have also been observed for many species (Stadler and Dixon, 2008). The family: Lycaenidae is traditionally divided into the subfamilies of the blues (Polyommatinae), the coppers (Lycaeninae), the hairstreaks (Theclinae) and the harvesters (Miletinae). Adults are small, under 5 cm usually, and brightly coloured, sometimes with a metallic gloss. Larvae are often flattened rather than cylindrical, with glands that may produce secretions that attract and subdue ants. Their cuticles tend to be thickened. Some larvae are capable of producing vibrations and low sounds that are transmitted through the substrates they inhabit. They use these sounds to communicate with ants. Adult individuals often have hairy antenna-like tails complete with black and white annulated (ringed) appearance. Many species also have a spot at the base of the tail and some turn around upon landing to confuse potential predators from recognizing the true head orientation. This causes predators to approach from the true head end resulting in early visual detection. Lycaenids are diverse in their food habits and apart from phytophagy, some of them are entomophagous feeding on aphids, scale insects, and ant larvae. Some lycaenids even exploit their association with ants by inducing ants to feed them by regurgitation, a process called trophallaxis. Not all lycaenid butterflies need ants, but about 75% of species associate with ants, a relationship called myrmecophily. These associations can be mutualistic, parasitic, or predatory depending on the species. In some species, larvae are attended and protected by ants while feeding on the host plant, and the ants receive sugar-rich honeydew from them, throughout the larval life, and in some species during the pupal stage. In other species, only the first few instars are spent on the plant, and the remainder of the larval lifespan is spent as a predator within the ant nest. It becomes a parasite, feeding on ant regurgitations, or a predator on the ant larvae. The caterpillars pupate inside the ant's nest and the ants continue to look after the pupa. Just before the adult emerges the wings of the butterfly inside the pupal case detach from it, and the pupa becomes silvery. The adult butterfly emerges from the pupa after three to four weeks, still inside the ant nest. The butterfly must crawl out of the ant nest before it can expand its wings. Several evolutionary adaptations enable these associations and they include small glands on the skin of the caterpillars called "pore cupola organs". Caterpillars of many species, except those of the Riodininae, have a gland on the seventh abdominal segment that produces honeydew and is called the "dorsal nectary gland" (also called "Newcomer's gland"). An eversible organ called the "tentacular organ" is present on the eighth abdominal segment (third segment of thorax in the Riodininae) and this is cylindrical and topped with a ring of spikes and emits chemical signals which are believed to help in communicating with ants.

Subfamilies of Family: Lycaenidae

Many taxonomists include only the Lycaeninae, Theclinae, Polyommatinae, Poritiinae, Miletinae and Curetinae under the Lycaenidae. The tribe Aphnaeini of the subfamily Theclinae which includes the genus *Chrysoritis* is sometimes listed as separate subfamily. A few authorities still include the family Riodinidae within the Lycaenidae. The monotypic former subfamily Styginae represented by *Styx infernalis* from the Peruvian Andes has been placed within the subfamily Euselasiinae of the family Riodinidae. (Brower Andrew, 2007).

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Lycaenidae Butterfly Diversity of Mayureshwar Wildlife Sanctuary of Baramati Tehsil in Pune district (India) (Table-1 and Fig.1):

The Lycaenidae is a family comprising several thousand species, majority of which are small in size and with a rapid flight. Many are brilliantly coloured, and this is often the result of interference effects caused by the microstructure of the wings. Eyes may be smooth or hairy, often with a border of dense white scales. Labial palps usually protrude forward, or are slightly ascending. Antennae are half the length of the forewing or slightly shorter, with a variable but usually long club. All legs are fully functional in both sexes, although the forelegs of the male are less well developed, and smaller, than in the female. All legs have a pair of claws, with the exception of the male foreleg which has a single claw. In some genera there are spines on the tibia. The number of veins on the forewing is generally reduced to 11 or even 10 with vein 8 and possibly vein 9 absent. The cell is narrow when compared with other families. The undersides of the wings typically differ greatly from the upper sides, often consisting of a pattern of spots. Sexual dimorphism is usually well-defined. In some genera there is a short tail at vein 2 of the hindwing. Androconial scales are usually present on upper side of male forewing.

The larval instars of lycaenidae of Mayureshwar Wildlife Sanctuary of Baramati Tehsil in Pune district (India) are found busy in appeasing the ant population. The ants as usual are aggressive and in the forest they feed on the butterfly larvae. The larval instars of lycaenidae of Mayureshwar Wildlife Sanctuary of Baramati Tehsil in Pune district (India) were often at the sacrifice of principles *appeased* the predator by accepting ant's demands. Myrmecophily among lycaenid caterpillars differs from the associations of hemipterans because caterpillars feed on plant tissues, not phloem sap, and therefore do not continually excrete honeydew. Caterpillars of lycaenid butterflies have therefore evolved specialized organs that secrete chemicals to feed and appease ants. The secretions are a mixture of sugar and amino acid which in synergy is more attractive to the ants than either component in its own. Butterflies of Family: Lycaenidae recorded at Mayureshwar Wildlife Sanctuary of Baramati Tehsil Dist. Pune (India) are listed in table-1.

Table 1. Butterflies of Family: Lycaenidae recorded at Mayureshwar Wildlife Sanctuary of Baramati Tehsil Dist. Pune (India).

Serial No.	Common Name	Scientific Name	Food Plants preferred by Larval Stages	Relative Abundance
1.	Western Centaur Oakblue	*Arhopala pseudocentaurus* Doubleday	*Terminalia paniculata* L.	Uncommon
2.	Yamfly	*Loxura atymnus* Stoll.	*Dioscorea* sp.	Uncommon
3.	Common Imperial	*Cheritra freja* Fabricius.	*Cinnamonum* sp.	Common
4.	Common Tit	*Hypolycaena erylus* Godart.	*Cinnamonum* sp.	Common
5.	Copper Flash	*Rapala pheretima* Hewitson.		Uncommon
6.	Indian Red Flash	*Rapala airbus* Fabricius.	*Melastoma malabathricum* L.	Common
7.	Long – Banded	*Spindasis lohita* Horsfield	*Dioscorea* spp.,	Uncommon

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	Silverline		*Psidium guajava* L.	
8.	Common Ciliate Blue	*Anthene emolus* Godart.	*Terminalia paniculata* L.	Rare
9.	Common Pierrot	*Castalius rosimon* Fabricius.	*Zizypus* sp.	Common
10.	Zebra Blue	*Leptotes plinius* Fabricius	*Mimosa* sp.	Uncommon
11.	Common Lineblue	*Prosotas nora* C. Felder.	*Acacia* sp., *Mimosa* spp.	Common
12.	Common Cerulean	*Jamides celeno* Cramer.	*Xylia xylocarpa* L.	Common
13.	Pea Blue	*Lampides boeticus* L.	*Pisum sativum* L.	Uncommon
14.	Dark Grass Blue	*Zizeeria karsandra* Moore.	*Amaranthus spinosus* L., *Polygonum* spp.	Very Common
15.	Pale Grass Blue	*Pseudozizeeria maha* Kollar.	*Oxalis corniculata* L.	Very Common
16.	Lesser Grass Blue	*Zizina otis* Fabricius.	*Vicia* sp.	Very Common
17.	Quaker	*Neopithecops zalmora* Butler.		Common
18.	Gram Blue	*Euchrysops cnejus* Fabricius.	*Acacia* spp., *Pisum sativum* L.	Common
19.	Lime Blue	*Chilades lajus* Stoll.	*Citrus* sp.	Very Common
20	Punchinello	*Zemeros flegyas* Cramer	*Maesa* spp.	Common

Fig. / Plate -1 : Butterflies of Family: Lycaenidae recorded at Mayureshwar Wildlife Sanctuary of Baramati Tehsil Dist. Pune (India).



Western Centaur Oakblue, *Arhopala pseudocentaurus* (L).



Yamfly, *Loxura atymnus* Stoll.



Common Imperial, *Cheritra freja* Fabricius.



Common Tit, *Hypolycaena erylus* Godart.

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 Copper Flash, *Rapala pheretima* Hewitson.	 Indian Red Flash, *Rapala airbus* Fabricius.	 Long – Banded Silverline, *Spindasis lohita* Horsfield	 Common Ciliate Blue, *Anthene emolus* Godart.
 Common Pierrot, *Castalius rosimon* Fabricius.	 Zebra Blue, *Leptotes plinius* Fabricius.	 Common Lineblue, *Prosotas nora* C. Felder.	 Common Cerulean, *Jamides celeno* Cramer.
 Pea Blue, *Lampides boeticus* L.	 Dark Grass Blue, *Zizeeria karsandra* Moore.	 Pale Grass Blue, *Pseudozizeeria maha* Kollar.	 Lesser Grass Blue, *Zizina otis* Fabricius.
 Quaker, *Neopithecops zalmora* Butler.	 Gram Blue, *Euchrysops cnejus* Fabricius.	 Lime Blue, *Chilades lajus* Stoll.	 Punchinello, *Zemeros flegyas* Cramer

The larvae of many lycaenid butterflies (Lepidoptera: Lycaenidae) interact with ants in relationships ranging from brood parasitism in ant colonies to mutualism in which both species benefit. Approximately 60% of the ant-associated lycaenid species are facultative myrmecophiles that are tended by several different ant species, usually on the larval host plant (Pierce et al. 2002). Lycaenid larvae in such

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relationships generally emit semio-chemicals from a pair of tentacular organs and secrete a sugar-rich solution from a dorsal nectary organ to attract and retain their ant guards (Axén *et al*. 1996; Axén 2000; Daniels *et al*. 2005), which then protect the larvae from predators and parasitoids (Pierce & Mead 1981; Fiedler *et al*. 1996). Additionally, larvae of some lycaenid species pupate inside ant nests, where the ants presumably protect them until adult eclosion (Wagner 1995; Dejean & Beugnon 1996). Thus, these associations entail an exchange of goods and services that usually results in net benefits for both partners (Pierce *et al*. 1987; Cushman *et al*. 1994). However, there is often substantial variation in quality among potential partners in facultative, diffuse mutualistic systems that may result in negative or neutral consequences for the survival and performance of the interacting species (Bronstein 2001; Miller 2007). Evaluating partner quality in purportedly mutualistic relationships is necessary to understand the ecological conditions and evolutionary processes
that influence the outcome of the relationship (Bshary & Grutter 2002; Ness *et al*. 2006). A central question in research on lycaenid-ant mutualisms is how interactions with different ant species affect larval performance (Axén 2000; Fraser *et al*. 2001; Weeks 2003). The physiological cost of provisioning ants with a sugar-rich exocrine secretion leads to reduced growth of anttended larvae in some systems (Pierce *et al*. 1987; Baylis & Pierce 1992), but growth of ant-tended larvae in other systems is similar to or greater than that of untended larvae (Fiedler & Hölldobler 1992; Cushman *et al*. 1994; Wagner & Del Rio 1997; Fraser *et al*. 2001). Because pupal mass is often correlated with adult reproductive output in Lepidoptera (Gotthard 2008), the growth consequences for larvae of ant tending could have subsequent effects on individual fitness (Elgar & Pierce 1988). Furthermore, because the relative importance of adult size and timing of adult emergence may differ between conspecific males and females (Fagerstrom & Wiklund 1982; Gotthard *et al*. 2000), in some lycaenid species there are sex differences in the effects of ant tending (Fiedler & Hölldobler 1992). Assessing the effects of anttending on lycaenid larvae and identifying the factors that explain variation in the interaction among and within species are central issues for furthering our understanding of these complex
relationships. Larvae of the imperiled Miami blue butterfly, *Cyclargus thomasi bethunebakeri* (Comstock & Huntington) (Lycaenidae: Polyommatinae), associate with several species of ants (Minno & Emmel 1993; Smith *et al*. 1994; Saarinen & Daniels 2006). Florida Fish and Wildlife Conservation Commission (2003) and Saarinen & Daniels (2006) accepted the fact of poor knowledge about the costs and benefits of this relationship. In addition to reporting new observations of ant tending in the wild and under laboratory conditions, our study is the first to quantify experimentally the effects of ant tending on performance of Miami blue larvae. Specifically, the present attempt on Lycaenidae Butterfly Diversity of Mayureshwar Wildlife Sanctuary of Baramati Tehsil in Pune district (India) observed the behavioral components of interactions between Miami blue larvae and different ant species in the field and in the laboratory (Dr. APIS; Shrikrupa Residence, Malegaon Colony, Tal. Baramati; Dist. Pune 413115 India) and raised larvae with several ant species to assess the nature of these interactions. This attempt then quantified the effects of ant tending and butterfly sex on larval survival, time until pupation, mass at pupation, and length of pupation with an experiment in which we raised larvae with 2 ant species and a no-ant control. This attempt on Lycaenidae Butterfly Diversity of Mayureshwar Wildlife Sanctuary of Baramati Tehsil in Pune district (India) also noted the location of pupation for larvae in this experiment. The implications of the attempt for the conservation of wild Miami blue butterfly populations and future reintroduction efforts

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are preferred for discussion. Relationships between lycaenid butterfly larvae and ants range dramatically in the effects on
the interacting species. Previous studies have suggested that some ant species may depredate Miami blue butterfly larvae or may opportunistically tend larvae without providing protection against predators or other benefits (Saarinen & Daniels 2006). However, through both field observations and laboratory trials, we recorded a universal tending response among ants consistent with a mutualistic interaction. Indeed, including the observations we report here, a total of 17 ant species have been observed tending Miami blue larvae either in wild populations, in reintroduction sites following releases of captive raised larvae or in the laboratory (Saarinen & Daniels 2006; Carroll & Loye 2006). We have not observed any depredation of Miami blue larvae by ants in the field, and laboratory trials suggest that even ant species identified by Saarinen & Daniels (2006) as potential predators in fact tend larvae in ways consistent with a mutualistic interaction. These results are notable for the large number of potential ant partners, the consistency of behaviors toward larvae among distantly related ant taxa and the nearly complete lack of obviously antagonistic interactions. Despite the high diversity of potential ant partners, our observations suggest that only a small subset of ant species accounts for the vast majority of interactions with Miami blue butterfly larvae in the field. Previous studies have reported that ant species in the genus *Camponotus* most commonly tended larvae (Minno & Emmel 1993; Carroll & Loye 2006; Saarinen & Daniels 2006), and we most commonly found *C. floridanus* and *C. planatus* associated with wild and recently released larvae. Notably, this pattern was consistent across 3 sites (BHSP, BNP, and DJSP) that likely differ dramatically in ant community composition (Deyrup *et al.* 1988). There are at least 4 likely explanations for the apparent reciprocal affinity between Miami blue larvae and *Camponotus*. First, *Camponotus* commonly forage on nickerbean for plant exudates, honeydew-producing Hemiptera, and insect prey even in sites where Miami blues do not occur, so frequent tending could be opportunistic association resulting from high rate of encounters compared to other potential ant partners. Second, after discovering Miami blue larvae, even those tended by other ant species, *Camponotus* may competitively exclude other ants from interacting with them through constant tending and defense. Third, following initial contact, the Miami blue larvae may allocate
more resources to retaining *Camponotus* compared to other ant species because *Camponotus* are higher quality defenders. Finally, *Camponotus* are quite large and active and therefore researchers may be more likely to find larvae tended by these ants. Larvae of some facultatively ant-tended lycaenid species pupate inside ant nests (e.g., Wagner 1995), but this has not been previously reported for the Miami blue butterfly. We found that a higher than expected number of larvae pupated in the ant harborages in the laboratory when tended by *C. floridanus* and no larvae pupated in that location when kept with *L. humile* or raised without ants, suggesting that this aspect of the relationship may have been overlooked. Clearly, future studies are required to elucidate the precise mechanisms that account for the persistent and geographically widespread association between *Camponotus* species, particularly *C. flori- danus* and *C. planatus* (and possibly *C. inequaelis*), and Miami blue larvae. In most facultative ant-lycaenid mutualisms,
the primary direct cost for the lycaenid larvae is metabolic expense required to produce sugary secretions for ant defenders (Pierce et al. 1987; Daniels et al. 2005). Because the secretions are induced by ant tending (Agrawal & Fordyce 2000), we might expect to find reduced larval growth rate or pupal mass in ant-tended larvae. In our experimental assessment of ant effects on performance of Miami blue butterfly

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larvae, both *C. floridanus* and *L. humile* almost constantly tended larvae and we frequently observed both species consuming secretions from the dorsal nectary organ. Carroll & Loye (2006) found that *Camponotus* sp. raised with Miami blue larvae lived longer than ants raised without any food source, demonstrating that larval secretions are nutritionally valuable for tending ants. However, contrary to theoretical predictions and the results of studies in similar ant-lycaenid systems, we found no effect of ant presence on any of our measurements of larval performance. It is possible that these secretions are less metabolically expensive than some studies have suggested or that ants tend larvae even when they receive only small nutritional rewards (Fiedler & Saam 1995). Alternatively, larvae may compensate for metabolic expenses of provisioning ants by feeding more efficiently when tended (Fiedler & Hölldobler 1992; Wagner & del Rio 1997). If the latter is true for Miami blue butterfly larvae, we may have found no effect of ant association on larval performance because increased growth of tended larvae offset the costs of the sugary secretions. Regardless of the specific mechanism, it appears that the net costs of ant tending for Miami blue butterflies do not substantially affect their larval development compared to untended conspecific larvae. The primary benefit of ant association for lycaenid larvae is defense against natural enemies (Atsatt 1981; Pierce & Mead 1981; Weeks 2003). We did not test this important aspect of the relationship for Miami blue butterfly larvae in this study, nor have we observed ants actively protecting larvae against attack by predators or parasitoids in the wild. However, in the laboratory *C. floridanus* displayed strong defensive behaviors (e.g., rapidly circling larvae, recruiting nearby workers and lunging at forceps) when disturbed, particularly when we moved Miami blue butterfly larvae to new host plant. The large size of this ant species and nearly constant tending may serve as a visual deterrent to potential attackers. Although *L. humile* workers assiduously tended Miami blue larvae in our experiment, they are substantially smaller than *C. floridanus* and did not show such a strong defensive response; instead, they usually ran away from the larvae and source of disturbance. Despite these qualitative observations, it is important to emphasize that we have no definitive evidence from this study that *C. floridanus* are more effective defenders of Miami blue butterfly larvae than small-bodied ant species. Given the apparently small physiological costs for Miami blue larvae of associating with ants, any predator or parasitoid deterrence provided by ant defenders could substantially increase their probability of survival to the adult stage. Male and female Lepidoptera larvae may have divergent developmental strategies, and may therefore exhibit variation in behaviors, such as foraging or prolonging the larval period that represent trade-offs between growth and mortality (Gotthard 2008). In lycaenid larvae, such differences could result in sex-specific interactions with ants, particularly in species for which timing of adult emergence and adult size have different effects on the relative reproductive success of males and females (Elgar & Pierce 1988). Indeed, Fiedler & Hölldobler (1992) found that *Polyommatus icarus* males benefited from ant association through increased pupal mass, but ant tending appeared to be energetically costly for females. This species has a strongly protandrous mating system with frequent male-male competition for access to females (Lundgren 1977), so it is reasonable that male larvae would interact with ants to optimize adult size as long as the costs to development time were not too great. Similarly, Baylis & Pierce (1992) found that male *Jalmenus evagoras* lost less mass from secretions for ants during the nonfeeding, prepupal instar. By contrast, studies on other lycaenid species have found no sex-related differences in ant association (e.g., Fraser et al. 2001). It is worth noting that most experiments testing lycaenid larval performance with and without ants have not recognized sex as a potentially important predictor of the interaction and its effects. We found that male and female Miami blue larvae differed in some

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performance parameters, but the sex x ant treatment term did not explain a significant amount of variation in any of the analyses.

As such, our results suggest that Miami blue larvae did not have sex-specific costs or benefits of interacting with ants, at least under our experimental conditions. The state-mandated management plan for the Miami blue butterfly identified examining the relationship between larvae and ants as one of the research goals to inform conservation efforts (Florida Fish and Wildlife Conservation Commission 2003). Saarinen & Daniels (2006) generated further interest in the implications of this relationship for protecting the Miami blue by suggesting that some ant species, particularly the nonnative *Solenopsis invicta* and *Pseudomyrmex gracilis*, could be predators of Miami blue larvae. Indeed, non-native ants can disrupt coevolved mutualistic interactions through competition with native ants or failure to provide the benefits to partner species (Ness & Bronstein 2004). The ant fauna of the Florida Keys contains numerous nonnative species, including some that are extremely invasive and have been implicated as major predators of arthropods (Deyrup et al. 1988; Deyrup et al. 2000). However, we found a universal tending response toward Miami blue larvae and very little antagonism across a wide range of ant species, including those previously identified as potential predators. This is a similar result to studies on honeydew-producing Hemiptera that have generally mutualistic relationships with ants, including non-native species (Helms & Vinson 2003; Mondor & Addicott 2007). Different ant species may not have equivalent effects on Miami blue larvae but, based on our observations, we doubt that many ant species regularly depredate larvae. We suggest that ants may be important for protecting larvae from natural enemies, but the identity of the ant attendants may not be particularly important for other measures of larval performance. Furthermore, because the 2 ant species that most commonly tend larvae in the wild and show a strong defensive response, *C. floridanus* and *C. planatus*, are common throughout southern Florida, it is likely that at least 1 of these species would be present at any potential reintroduction site. The results in the attempt suggest that the facultative and diffuse interactions between ants and Miami blue larvae are unlikely to be the most important determinant of conservation success for the imperiled butterfly.

The ants are normally predators of butterfly larvae (caterpillars), however lycaenids have evolved a range of mechanisms to overcome predation. These mechanisms either deter the ants, or attract them by the secretion of compounds that are so attractive to ants that they will protect the larvae instead. Associations between the ants and the lycaenid larvae range from mutually beneficial relationships, where the ants get fed in return for feeding and/or protecting the larvae (for example, from parasitic wasps and predatory flies), to relationships where the larvae actually prey upon the ants. Variations in the associations between ants and lycaenid larvae relate to the types of glands present and the chemicals produced by any one species of lycaenid. Three types of glands include: small glands; large glands and metathorasic glands. The small, single-celled glands are scattered over the caterpillar's skin, present in all lycaenids, which produce substances that attract or appease ants. These are called “Pore Cupola Organs”. The large gland located in the middle of the seventh abdominal segment, present in most lycaenids (except the subfamily Riodininae), which produces a thick liquid made up of sugars and amino acids. This is called the “Dorsal Nectory Organ” or “Honey Gland'. The metathorasic glands are found on the eighth abdominal segment in most lycaenid subfamilies (but located on the metathorax (third segment of the thorax) in Riodininae). These are called “Dorsal Eversible Organs” or “Tentacular Organs”. They take the form of long cylindrical tubes that can be everted (turned inside out), and are topped with a brightly coloured ring of

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spikes. When the tubes are retracted, a pale depression surrounded by hairs indicates their position. The function of these glands may be to attract or repel ants through the release of volatile chemicals, but this is not certain.

Ant attendance also varies with the larval (caterpillar) developmental stage (instar), with the later instars getting more attention than earlier ones. Other factors that may influence relationships are season, habitat and time of day.

The categories of associations of lycaenids with ants are as below:

1. Larvae that are not attended by ants, or only rarely associated with ants.
2. Larvae that are frequently attended by ants. These are called *myrmecophilous* ('ant-loving') associations. Within this category, there are two types of association: obligate myrmecophily facultative and myrmecophily. In obligate myrmecophily, larvae are always or regularly attended by a large number of ants. In facultative myrmecophily, larvae are only sometimes attended, or only attended by a small number of ants.
3. Larvae that either prey on ants or are fed by ants. These are called *aphytophagous* ('non-plant-eating') associations. In this category there are larvae that prey upon immature ants or larvae that feed on the regurgitations of ants. This category also includes species that prey upon, or feed on, secretions produced by bugs (Order Hemiptera).
4. Larvae that are preyed upon by ants. This is a much smaller category. For example, the meat ant, *Iridomyrmex purpureus*, preys on the larvae of azure butterflies (*Ogyris* sp.) and a species of bull ant (*Myrmecia* sp.) preys on larvae of the Imperial Hairstreak (*Jalmenus evagoras*). Interestingly, both of these ant species actually attend other lycaenid larvae (*Jalmenus ictinus* and *Theclinesthes*, respectively).

These associations between lycaenids and ants usually benefit both partners (known as mutualism). However, even though the ants may benefit from harvesting food rewards offered to them by lycaenid larvae, they do not depend on lycaenids for survival and reproduction. Instead they forage on a wide range of other food resources. Similarly, most lycaenid larvae feed on the young leaves, flowers and seeds of plants, and are not completely dependent upon the ants they may be associated with. A small number of Australian lycaenids live as parasites within ant nests where they feed on the immature brood of their host ant. Introduced pest ants are a direct threat to lycaenid butterflies because they compete with or destroy the indigenous ants upon which these butterflies depend (https://australianmuseum.net.au/lycaenid-butterflies-and-ants).

Wing Pattern Diversity in the Lycaenidae Butterflies

Closely related species of lycaenid butterflies are determinable, in part, by subtle differences in wing pattern. The present attempt on "Lycaenidae Butterfly Diversity of Mayureshwar Wildlife Sanctuary of Baramati Tehsil in Pune district (India)" reporting significance of female wing patterns for significant mate-recognition signal in some populations of two recently diverged species. In field experiments, we observed that males from a *Lycaeides idas* population and an alpine population of *L. melissa* preferentially initiate courtship with conspecific females. A morphometric study indicated that at least two wing pattern elements were important for distinguishing the two species: hindwing spots and orange crescent-shaped pattern elements called aurorae. The present attempt on "Lycaenidae Butterfly Diversity of Mayureshwar Wildlife Sanctuary of Baramati Tehsil in Pune district (India)" deceived male L. idas into initiating courtship with computer generated paper models of heterospecific females when these

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pattern elements were manipulated, indicating that the wing pattern elements that define the diversity of this group can be effective mate recognition signals. The great diversity of pattern and colour found on the wings of butterflies inspired much early evolutionary thought (Bates, 1862; Wallace, 1865; Mu¨ ller, 1878; Darwin, 1880). Investigators appreciated the striking contrast in wing coloration among species and the subtle variation within species and among closely related species (Wallace, 1865; Darwin, 1880). Since that time, our understanding of the development and evolution of butterfly wing patterns has greatly increased. The wing pattern and coloration exhibited by many butterfly species is genetically controlled and complex (Nijhout, 1991; Carroll *et al*., 1994; Koch et al., 1998; Brakefield & French, 1999). Some species of butterflies exhibit phenotypic plasticity of wing coloration and pattern in response to environmental cues, such as temperature and day length (Shapiro, 1976; Brakefield et al., 1996; Brakefield & French, 1999), and in response to larval hostplant (Knu¨ ttel & Fiedler, 2001). The functional significance of wing coloration and pattern has been investigated for many butterflies and many adaptive hypotheses, including thermoregulation (Watt, 1968; Kingsolver, 1985; Van Dyck & Matthysen, 1998), crypsis (Scoble, 1992), and inter- and intraspecific signalling have been proposed. Considering the conspicuous appearance of many butterfly wings, it is not surprising that their functioning as signal mechanisms has received the most attention. For example, wing coloration has been shown to be an effective aposematic signal (Brower, 1958; Platt & Brower, 1968; Ohsaki, 1995; Uesugi, 1996; Kapan, 2001). Conspicuous patterns, coloration and melanization of butterfly wings have also been found to function as mate recognition signals (Crane, 1955; Stride, 1957; Lederer, 1960; Silberglied, 1984; Wiernasz, 1989, 1995; Wiernasz & Kingsolver, 1992; Vane-Wright & Boppre, 1993; Warzecha & Egelhaaf, 1995). For example, Jiggins et al. (2001) found that the conspicuously different morphs of a Heliconius species mate assortatively. Assortative mating is a mating pattern and a form of sexual selection in which individuals with similar phenotypes mate with one another more frequently than would be expected under a random mating pattern. Some examples of similar phenotypes are body size, skin coloration/pigmentation, and age. Assortative mating, also referred to as positive assortative mating or homogamy, can increase genetic relatedness within the family. Assortative mating is the inverse of disassortative mating (also known as negative assortative mating or heterogamy), in which individuals with dissimilar genotypes and/or phenotypes mate with one another more frequently than would be expected under random mating. Disassortative mating reduces the genetic similarities within the family. Positive assortative mating occurs more frequently than negative assortative mating. In both cases, the nonrandom mating pattern result in a typical deviation from the Hardy–Weinberg principle (which states that genotype frequencies in a population will remain constant from generation to generation in the absence of other evolutionary influences, such as "mate choice" in this case). Assortative mating has reproductive consequences. Positive assortative mating increases genetic relatedness within a family, whereas negative assortative mating accomplishes the opposite effect. Either strategy may be employed by the individuals of a species depending upon which strategy maximizes fitness and enables the individuals to maximally pass on their genes to the next generation. For instance, in the case of eastern bluebirds, assortative mating for territorial aggression increases the probability of the parents obtaining and securing a nest site for their offspring. This in turn increases the likelihood of survival of the offspring and consequently fitness of the individuals (*Jacobs, et al, 2014).* In birds whose coloration represents wellbeing and fecundity of the bird, positive assortative mating for color increases the chances of genes being passed on and of the offspring being in good condition. Also, positive assortative mating

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for behavioral traits allows for more efficient communication between the individuals and they can cooperate better to raise their offspring

Additionally, in lycaenidae butterflies, ultraviolet reflectance patterns of butterfly wings can be important for inter- and intraspecific mate discrimination (Obara, 1970; Rutowski, 1977, 1981; Silberglied, 1984; Brunton & Majerus, 1995; Knu¨ ttel & Fiedler, 2001). Despite these examples, subtle differences in pattern are not widely believed to play a significant mate-signalling role.

All the studies of mate recognition mentioned above have investigated the significance of relatively conspicuous differences between species. Taxonomists often discriminate among closely related butterfly taxa using subtle differences in wing pattern detail. This is especially true for the family Lycaenidae. Commonly called blues, hairstreaks, metalmarks and coppers, the Lycaenidae is the most species-rich group of butterflies comprising between 30 and 50% of true butterflies (Papilionoidea) (Robbins, 1982). However, the functional significance of the complex patterns characteristic of lycaenid wings has largely been unexplored. In this study, we examined whether the wing pattern differences within a North American lycaenid species

complex act as effective mate recognition signals that may contribute to assortative mating. Lycaeides idas (Linnaeus) and L. melissa (W. H. Edwards) are broadly sympatric across much of North America (Scott, 1986). Genetic variation at 10 allozyme loci and mitochondrial DNA sequence variation fails to distinguish the two, suggesting that they are recently diverged (Nice & Shapiro, 1999). However, these butterflies are determinable by differences in wing patterns and male genitalic morphology making them good morphological species. They also maintain important ecological differences. In the western USA, L. idas occupy mid-elevation, wet meadow habitats. Lycaeides melissa occupies much drier habitats: alpine steppe and cultivated agricultural alfalfa (Medicago sativa) fields. Both species mate on or near their host plants. Courtship behaviour begins with males patrolling (Scott, 1974) nearly continuously throughout the flight season, searching for stationary females. Stationary females assume a characteristic head-down posture with their wings held closed exposing the ventral hindwing surface (Pellmyr, 1982). Males approach and flutter around stationary females; this initial approach is followed by a series of stereotypical courtship behaviors that lead to copulation (Lundgren & Bergstrom, 1975; Pellmyr, 1982).

Conclusively enough, the Lycaenidae butterflies of study area seems to be the excellent field of academic and social attraction. Coppers are especially dominant in the study area, blues are richest, population depending on the type of vegetation. And hairstreaks in the study area are particularly abundant through the year. The adults of lycaenidae are typically small to tiny and often brilliantly colored--iridescent blues, bright reds, and oranges. Adult males as well as the females have three pairs of walking legs. Most of the male lycaenidae butterflies have fused segments in their front legs. Visiting the flowers on vegetation for nectar appeared significant feature of male lycaenidae butterflies. Some of them harvesters feed on wooly aphid honeydew and some hairstreaks feed on aphid honeydew or bird droppings. Females lay single. The egg of lycaenidae butterflies is small, sea urchin shaped and laid on host leaves or flower buds. Incubation of fertilized eggs vary according to species and the resulting caterpillars are typically slug-shaped. In many species of lycaenidae butterflies, caterpillars depend on ants for protection, so caterpillars produce sugary secretions that are collected by the ants. Most species overwinter in either the egg or pupal stage. Ants that interact with myrmecophilous lycaenidae caterpillars and myrmecophytes are highly associated species. Both, ants and myrmecophilous lycaenidae caterpillars are adapted to interact with each other. Therefore, ants and myrmecophilous lycaenids provide ideal model systems in

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which to explore the magnitude, dynamics, and frequency of mutualism in nature. The populations of lycaenidae butterflies tend to be localised, reflecting the patchy co-occurrence of the larval plant food and attendant ants. These factors make many lycaenids very vulnerable to habitat disturbance, and many species are threatened with extinction. The concept of "Myrmecophilous Lycaenids" should be explored for the qualitative insect pest control.

Conclusion

This family has developed a close associated with ants. In many species the larva has a specialised "honey gland", known as the Newcomer's gland, on the 7th abdominal segment, that is usually developed in the 2nd instar. This gland exudes a sweet cocktail of amino acids that is attractive to ants, which, in turn, offer the larva a level of protection. Ants can also be found tending to pupae and accompaning adults during their emergence. The association is most specialised in the Large Blue (*Maculinea arion*) where the late-instar larvae feed on ant grubs, and the pupa is formed within the ant nest. As with the other hairstreak butterflies, perching adults move their hind wings up and down. The tails on the hind wings with their associated spots resemble a head. The movement of the tails is believed to attract a potential predator's attention to that part of the wings which then is torn away allowing the butterfly to escape.

The Great Purple Hairstreak Butterflys habitats are mostly moist hardwood forests, bottomlands, swamps and trees having Mistletoe nearby as this is its larvae host plant.

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References:

Ackery, P. R., R. de Jong, and R. I. Vane-Wright. 1999. The butterflies: Hedyloidea, Hesperioidea, and Papilionoidea. Pages 264-300 in: Lepidoptera: Moths and Butterflies. 1. Evolution, Systematics, and Biogeography. Handbook of Zoology Vol. IV, Part 35. N. P. Kristensen, ed. De Gruyter, Berlin and New York.

AGRAWAL, A. A., AND FORDYCE, J. A. 2000. Induced indirect defence in a lycaenid-ant association: the regulation of a resource in a mutualism. Proc. Roy. Soc. B-Biol. Sci. 267: 1857-1861.

ATSATT, P. R. 1981. Lycaenid butterflies and ants – selection for enemy-free space. American Nat. 118: 638-654.

Australian Museum factsheets Accessed 4 November 2010 on the Wayback Machine.

AXÉN, A. H. 2000. Variation in behavior of lycaenid larvae when attended by different ant species. Evol. Ecol. 14: 611-625.

AXÉN, A. H., LEIMAR, O., AND HOFFMAN, V. 1996. Signalling in a mutualistic interaction. Anim. Behav. 52: 321-333.

B. Holldobler and E.O. Wilson (1994). Journey to the Ants, Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 1994.

Received:4 June 2018/Accepted:11 September 2018 /Published:3 December 2018

B. Holldobler and E.O. Wilson, (1990). The Ants, Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 1990.

B. Stadler and T. Dixon (2008). Mutualism: Ants and their insect partners, Cambridge: Cambridge University Press, 2008.

BAYLIS, M., AND PIERCE, N. E. 1992. Lack of compensation by final instar larvae of the myrmecophilous lycaenid butterfly, Jalmenus evagoras, for the loss of nutrients to ants. Physiol. Entomol. 17: 107-114.

BRONSTEIN, J. L. 2001. The costs of mutualism. American Zool. 41: 825-839.

Brower, Andrew V. Z. 2007. Riodinidae Grote 1895. Metalmarks, Erycinidae Swainson 1827 (see nomenclature section). Version 19 May 2007 [4] in The Tree of Life Web Project, [5]

Brower, Andrew V. Z. 2007. Riodinidae Grote 1895. Metalmarks, Erycinidae Swainson 1827 (see nomenclature section). Version 19 May 2007 [4] in The Tree of Life Web Project,

Brower, Andrew V. Z. 2008. Lycaenidae. Version 25 April 2008 (temporary). [2] in The Tree of Life Web Project, [3]

BSHARY, R., AND GRUTTER, A. S. 2002. Experimental evidence that partner choice is a driving force in the payoff distribution among cooperators or mutualists: the cleaner fish case. Ecol. Lett. 5: 130-136.

CALHOUN, J. V., SLOTTEN, R. J., AND SALVATO, M. H. 2002. The rise and fall of tropical blues in Florida: Cyclargus ammon and Cyclargus thomasi bethunebakeri. Holarctic Lepidoptera 7: 13-20. CARROLL, S. P., AND LOYE, J. 2006. Invasion, colonization, and disturbance; historical ecology of the endangered Miami blue butterfly. J. Insect Conserv. 10: 13-27.

CUSHMAN, J. H., RASHBROOK, V. K., AND BEATTIE, A. J. 1994. Assessing benefits to both participants in a lycaenid-ant association. Ecology 75: 1031-1041.

DANIELS, H., GOTTSBERGER, G., AND FIEDLER, K. 2005. Nutrient composition of larval nectar secretions from three species of myrmecophilous butterflies. J. Chem. Ecol. 31: 2805-2821.

DEJEAN, A., AND BEUGNON, G. 1996. Host-ant trail following by myrmecophilous larvae of Liphyrinae (Lepidoptera, Lycaenidae). Oecologia 106: 57-62.

DeVries, Philip J. 1992. Singing Caterpillars, Ants and Symbiosis. Scientific American, 267:76

DEYRUP, M. A., CARLIN, N., TRAGER, J., AND UMPHREY, G. 1988. A review of the ants of the Florida Keys. Entomol. 71: 163-176.

DEYRUP, M., DAVIS, L., AND COVER, S. 2000. Exotic ants in Florida. Trans. American Entomol. Soc. 126: 293-326.

ELGAR, M. A., AND PIERCE, N. E. 1988. Mating success and fecundity in an ant-tended lycaenid butterfly, pp. 59-75 In T. H. Clutton-Brock [ed.], Reproductive Success: Studies of Selection and Adaptation in Contrasting Breeding Systems. University of Chicago Press, Chicago, IL, USA

FAGERSTROM, T., AND WIKLUND, C. 1982. Why do males emerge before females? Protandry as a mating strategy in male and female butterflies. Oecologia 52: 164-166.

FARAWAY, J. J. 2006. Extending the Linear Model with R: Generalized Linear, Mixed-Effects and Nonparametric Regression Models. Chapman & Hall CRC Group. Boca Raton, Florida, USA.

FIEDLER, K., AND HÖLLDOBLER, B. 1992. Ants and Polyommatus icarus immatures (Lycaenidae) - Sex-related developmental benefits and costs of ant attendance. Oecologia 91: 468-473.

Received:4 June 2018/Accepted:11 September 2018 /Published:3 December 2018

FIEDLER, K., AND SAAM, C. 1995. Ants benefit from attending facultatively myrmecophilous Lycaenidae caterpillars—Evidence from a survival study. Oecologia 104: 316-322.

FIEDLER, K., HÖLLDOBLER, B., AND SEUFERT, P. 1996. Butterflies and ants: The communicative domain. Experientia 52: 14-24.

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION. 2003. Management plan: Miami blue Cyclargus (=Hemiargus) thomasi bethunebakeri. State of Florida, Tallahassee, Florida, USA.

FRASER, A. M., AXÉN, A. H., AND PIERCE, N. E. 2001. Assessing the quality of different ant species as partners of a myrmecophilous butterfly. Oecologia 129: 452-460.

GOTTHARD, K. 2008. Adaptive growth decisions in butterflies. Bioscience 58: 222-230.

GOTTHARD, K., NYLIN, S., AND WIKLUND, C. 2000. Mating opportunity and the evolution of sex-specific mortality rates in a butterfly. Oecologia 122: 36-43.

Hall J.P.W. & Harvey DJ. (2002) A survey of androconial organs in the Riodinidae (Lepidoptera). Zoological Journal of the Linnean Society, 136:171-197

HELMS, K. R., AND VINSON, S. B. 2003. Apparent facilitation of an invasive mealybug by an invasive ant. Insect. Soc. 50: 403-404.LUNDGREN, L. 1977. The role of intra- and inter-specific male: male interactions in Polyommatus icarus Rott. and some other species of blues (Lycaenidae). J. Res. Lepidoptera 16: 249-264.

https://australianmuseum.net.au/lycaenid-butterflies-and-ants

Jacobs, Anne C.; Fair, Jeanne M.; Zuk, Marlene (2014). "Coloration, Paternity and Assortative Mating in Western Bluebirds". International Journal of Behavioral Biology. 121: 176–186. doi:10.1111/eth.12327.

K. Fiedler, B. Holldobler, and P. Seufert, (1996). "Butterflies and ants: The communicative domain," Cellular and molecular life sciences, vol. 52, 1996, pp. 14-24.

Mathew, D. Trager and Jaret C. Danies (2009). Ant tending of Miami Blue butterfly larvae (Lepidoptera: Lycaenidae) Partener Diversity and effects on larval performance. Florida Entomologists 92 (3): 474 – 482.

MILLER, T. E. X. 2007. Does having multiple partners weaken the benefits of facultative mutualism? A test with cacti and cactus-tending ants. Oikos 116: 500- 512. MINNO, M. C., AND EMMEL, T. C. 1993. Butterflies of the Florida Keys. Scientific Publishers, Gainesville, Florida.

MONDOR, E. B., AND ADDICOTT, J. F. 2007. Do exaptations facilitate mutualistic associations between invasive and native species? Biol. Invasions 9: 623- 628.

N. Bluthgen, N.E. Stork, and K. Fiedler (2004). "Bottom-up control and co-occurrence in complex communities: honeydew and nectar determine a rainforest ant mosaic," Oikos, vol. 106, 2004, pp. 344-358.

Naomi E. Pierce, Michae, F. Braby, Alan Heath, David J. Lohman, John Mathew, Douglas B. Rand, Mark A. THE ECOLOGY AND EVOLUTION OF ANT ASSOCIATION IN THE LYCAENIDAE (LEPIDOPTERA) 47(1):259-267 [1]

NESS, J. H., AND BRONSTEIN, J. L. 2004. The effects of invasive ants on prospective ant mutualists. Biol. Invasions 6: 445-461.

NESS, J. H., MORRIS, W. F., AND BRONSTEIN, J. L. 2006. Integrating quality and quantity of mutualistic service to contrast ant species protecting Ferocactus wislizeni. Ecol. 87: 912-921.

Received:4 June 2018/Accepted:11 September 2018 /Published:3 December 2018

Pierce NE, Braby MF, Heath A, Lohman DJ, Mathew J, Rand DB, Travassos MA. 2002. The ecology and evolution of ant association in the Lycaenidae (Lepidoptera.) Annual Review of Entomology 47: 733-771.

PIERCE, N. E., AND MEAD, P. S. 1981. Parasitoids as selective agents in the symbiosis between lycaenid butterfly larvae and ants. Science 211: 1185-1187.

PIERCE, N. E., BRABY, M. F., HEATH, A., LOHMAN, D. J., MATHEW, J., RAND, D. B., AND TRAVASSOS, M. A. 2002. The ecology and evolution of ant association in the Lycaenidae (Lepidoptera). Annu. Rev. Entomol.47: 733-771.

PIERCE, N. E., KITCHING, R. L., BUCKLEY, R. C., TAYLOR, M. F. J., AND BENBOW, K. F. 1987. The costs and benefits of cooperation between the Australian lycaenid butterfly, Jalmenus evagoras, and its attendant ants. Behav. Ecol. Sociobiol. 21: 237-248.

PINHEIRO, J. C., AND BATES, D. M. 2002. Mixed Effects Models in S and S-Plus. Springer-Verlag. New York, USA.

Robbins, Robert K. 1981 The "False Head" Hypothesis: Predation and Wing Pattern Variation of Lycaenid Butterflies. American Naturalist, 118(5):770-775.

SAARINEN, E. V., AND DANIELS, J. C. 2006. Miami blue butterfly larvae (Lepidoptera: Lycaenidae) and ants (Hymeoptera: Formicidae): New information on the symbionts of an endangered taxon. Florida Entomol. 89: 69-74.

Scoble, MJ. 1992. The Lepidoptera: Form, Function and Diversity. Oxford University Press. ISBN 0-19-854952-0

SMITH, D. S., MILLER, L. D., AND MILLER, J. Y. 1994. The Butterflies of the West Indies and South Florida. Oxford University Press. New York, New York, USA.

TILLBERG, C. V., HOLWAY, D. A., LEBRUN, E. G., AND SUAREZ, A. V. 2007. Trophic ecology of invasive Argentine ants in their native and introduced ranges. Proc. Natl. Acad. Sci. U.S.A. 104: 20856-20861.

WAGNER, D. 1995. Pupation site choice of a North American lycaenid butterfly: The benefits of entering ant nests. Ecol. Entomol. 20: 384-392.

WAGNER, D., AND DEL RIO, C. M. 1997. Experimental tests of the mechanism for ant-enhanced growth in an ant-tended lycaenid butterfly. Oecologia 112: 424-429.

WEEKS, J. A. 2003. Parasitism and ant protection alter the survival of the lycaenid Hemiargus isola. Ecol. Entomol. 28: 228-232.

Received:4 June 2018/Accepted:11 September 2018 /Published:3 December 2018