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Heterospecific predation by the predatory soil mite Blattisocius mali (Acari: Blattisociidae) and its predation preference towards conspecific and heterospecific prey

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Abstract

The predatory soil mites *Blattisocius mali* and *Stratiolaelaps scimitus* share similar prey and habitats. This study explores heterospecific predation of various life stages of *B. mali* on *S. scimitus* developmental stages across different starvation periods and their predation preference towards conspecific and heterospecific eggs or larvae in the absence of shared prey at 25°C, 85 ± 5% RH, and a 16L:8D photoperiod. All fed developmental stages of *B. mali* consumed eggs and larvae of *S. scimitus*, although they did not kill or feed on *S. scimitus* deutonymphs and more advanced developmental stages. Very few *B. mali* females killed *S. scimitus* protonymphs, while other stages did not. Interestingly, the propensity of *B. mali* females to eat heterospecific eggs was not affected by the starvation period. However, their predation on heterospecific larvae increased with starvation up to 48 h and then stabilized. *Blattisocius mali* females, males, or deutonymphs showed a greater propensity towards heterospecific larvae compared to eggs across all the tested starvation periods. Notably, the proportion of *B. mali* protonymphs that ate heterospecific eggs was substantially higher than that of other stages, and males had a significantly greater tendency to prey on heterospecific larvae relative to other stages. When given a choice, all life stages of *B. mali* clearly distinguished between conspecific and heterospecific eggs, preferring to prey on conspecific eggs. In contrast, when selecting between conspecific and heterospecific larvae, they preferred to prey upon heterospecific larvae. This study suggests that *B. mali* may interact with *S. scimitus* and feed on their eggs and larvae, which may affect the biological control of pests.

Introduction

Interactions both within and between predator species play a crucial role in shaping predator-prey and predator-predator relationships. Understanding these interactions is essential for predicting how predators influence the natural and biological control of arthropod pests (Polis et al. 1989; Sih et al. 1998; Loosey and Denno 1999; Tsuchida et al. 2022). Two common forms of trophic interactions among predators include intraspecific competition, where individuals of the same species kill and consume one another, and interspecific competition, where different predator species engage in killing and consuming their heterospecific rivals (Polis et al. 1989; Elgar and Crespi 1992; Yadav and Mishra 2026). These phenomena are widespread across the animal kingdom (Polis et al. 1989; Elgar and Crespi 1992; Chi et al. 2026; Gong et al. 2026). Such interactions tend to intensify when prey is scarce, thereby providing additional food resources for predators (Polis et al. 1989; Schausberger 1997; Cai et al. 2026). Both types of predation can significantly influence the distribution and population sizes of the species involved. They often lead to spatial and temporal segregation, causing prey species to be displaced or confined to less optimal habitats or periods, thereby affecting their survival and abundance (Hurd and Eisenberg 1990; Moran et al. 1996; Walzer et al. 2001).

Interspecific competition can arise among predators within (intraguild) or outside (extraguild) their immediate ecological guilds. Intraguild predation (IGP) specifically occurs within biological control systems when one natural enemy attacks another species of natural enemy while simultaneously

competing for the same prey (Janssen et al. 2006). Beyond providing direct nutritional benefits, IGP can also diminish competition for shared prey and reduce the risk of predation on oneself or related species (Polis et al. 1989). This phenomenon can significantly impact ecological communities, influencing species diversity, population sizes, ecosystem stability, and the overall structure of food webs (Schausberger and Croft 2000a; Döker et al. 2021). Factors such as prey availability, predator density, and the frequency of predator encounters can promote IGP. Additionally, traits such as body size, feeding behaviour, dietary preferences, life history strategies, and habitat complexity play crucial roles in shaping the intensity and direction of IGP (Polis et al. 1989; Shakya et al. 2009; Mendel and Schausberger 2011). Generally, generalist predators tend to be more aggressive towards other predators compared to specialists (Schausberger and Croft 2000a), and they often gain equivalent or greater nutritional benefits from IGP (Schausberger and Croft 2000b). Such interactions are widespread in both terrestrial and aquatic ecosystems among generalist predators (Polis et al. 1989; Polis and Holt 1992; Chi et al. 2026; Liu et al. 2026). In biological control practices, different agents are often deployed together (Yano 2005). Sometimes, two or more species with complementary effects are released simultaneously. For example, Yano (2005) noted that an initial release of an easily reared predator is used as a preventative measure against pests. Once pest populations reach high levels, a second predator, often a generalist species that may be more challenging to mass-rear, is introduced to further suppress the pest population.

Soil-dwelling mites such as *Blattisocius mali* Oudemans (Acari: Blattisociidae) and *Stratiolaelaps scimitus* Womersley (Acari: Laelapidae) are generalist predators. Both species can prey upon various arthropod pests, including the mould mite *Tyrophagus putrescentiae* Schrank (Acari: Acaridae), fungus gnat *Lycoriella* sp., western flower thrips *Frankliniella occidentalis*, and nematodes (Brødsgaard et al. 1996; Enkegaard et al. 1997; Steiner et al. 1999; Navarro-Campos et al. 2016; Abbas et al. 2022; Asgari et al. 2023; Michalska et al. 2023). Studies have demonstrated that *B. mali* is particularly effective at suppressing *T. putrescentiae* populations (Jena et al. 2024, 2025a, b, 2026a, d; Michalska et al. 2025), showing strong potential to control mite infestations in stored flower bulbs and cucumber plants (Jena et al. 2026b, d). Similarly, *S. scimitus* has proven to be highly effective against thrips infesting greenhouse crops, and sciarid flies in horticultural and mushroom systems (Castilho et al. 2009; Lan et al. 2025; Chi et al. 2026). When *B. mali* is released into a crop, it may interact with other predatory mites, including *S. scimitus*, which are present both in natural environments, such as soil or litter, and also used in the biological control of crop pests or stored product pests (McMurtry and Croft 1997; McMurtry et al. 2013; Moreira and de Moraes 2015). These interactions can lead to competition or even predation among different predatory mite species, which might undermine the effectiveness of biological control efforts aimed at managing pests.

This study aimed to investigate the heterospecific predation of *B. mali* on *S. scimitus* immatures and its predation preference towards conspecific and heterospecific prey. Recognising that a predator's hunger level can influence its predatory behaviour (Zhang and Zhang 2022; Jena et al. 2026c), we expect that (1) prolonged starvation may increase *B. mali's* tendency to target heterospecific prey. Given that *B. mali* shows a higher predation rate on its own larvae compared to eggs (Jena et al. 2026c), we predict that (2) the degree of heterospecific predation may be greater on larval stages than on eggs. Considering that

female *B. mali* exhibits greater voracity than males (Jena et al. 2025a), we expect that (3) *B. mali* females are more likely to prey upon heterospecifics than males. Acknowledging the variation in predation rates across different life stages of *B. mali* towards prey (Jena et al. 2025a), we expect that (4) *B. mali* deutonymphs may engage more frequently in heterospecific predation than other developmental stages. Finally, based on previous findings that adult females of generalist predators can distinguish between conspecific and heterospecific prey and tend to prefer heterospecifics when given a choice (Schausberger 1999; Walzer and Schausberger 1999; Meszaros et al. 2007; Momen and Abdel Khalek 2009), we hypothesise that (5) *B. mali* may also show a preference for preying on heterospecifics when both options are available.

Materials and Methods

Predator and prey sources and rearing: general methods

The primary colony of the predatory mite *B. mali* was taken from the Department of Plant Protection of Warsaw University of Life Sciences (WULS), Warsaw, Poland. It has been kept on water-soaked foam pads with wheat bran serving as the growing medium, all within the same department at WULS (Jena et al. 2024, 2025a, b). Every week, the mites were provided with a blend of various life stages of *T. putrescentiae* for nourishment. The mites were housed in a climate-controlled room maintained at 23 ± 1°C, 85 ± 5% RH, and 16L:8D photoperiod.

The main colony of the predatory mite *S. scimitus*, provided as the Entomite-M formulation, was sourced from Koppert Polska. This colony was maintained in plastic containers measuring 120 mm in diameter and 200 mm in height, utilizing damp peat as a growing medium. The containers were sealed with lids featuring small vents for air circulation and were kept in a closed room at 23 ± 1°C with 95 ± 5% RH, all in complete darkness at the Department of Plant Protection at WULS. The acidic sphagnum peat, sourced from KIK Ziemskie Produkty Sp. z o.o. in Poland, had a pH level between 3.5 and 4.5, contained over 85% organic matter, had a salinity of less than 1.0 g/l, and consisted of particles ranging from 0 to 20 mm. Before use, the peat was sterilized in a Memmert steriliser at 100°C for 5 h and subsequently cooled with a fine mist of distilled water. The colony was provided with a weekly diet consisting of various life stages of *T. putrescentiae*. Efforts were made to ensure the colony remained moist and was protected from any contamination by harmful fungi.

To obtain an adequate number of eggs, the *T. putrescentiae* culture was sourced from and maintained at the mass-rearing facility of the Department of Plant Protection at WULS. This culture was maintained in glass Petri dishes using equal amounts of instant dry baker's yeast and wheat bran, and kept at 26°C and 95 ± 5% RH. The setup was kept in total darkness inside a Panasonic Sanyo Environmental Test Chamber (Jena et al. 2024).

To acquire eggs, larvae, protonymphs, and deutonymphs of *B. mali* for experiments, gravid *B. mali* females were randomly picked from the colony. Each was placed alone with a mix of life stages of *T.*

putrescentiae as their food in a Plexiglass cage chamber for 20 h before starting the experiments. The Plexiglass cage featured a round opening (8 mm), as detailed by Jena et al. (2024). These mite-containing cages were kept inside a desiccator at 25°C, 85 ± 5% RH, and 16L:8D photoperiod, all maintained in a Panasonic-cooled incubator (MIR-154-PE, Japan). After 20 h, the eggs produced were collected and reared with various life stages of *T. putrescentiae* as food to obtain larvae, along with well-fed protonymphs and deutonymphs. The newly hatched larvae were raised separately in individual cages without any food to produce unfed protonymphs. Older protonymphs, just before they were about to moult, were taken and kept without food to produce unfed deutonymphs. To obtain well-fed females and males, *B. mali* individuals were randomly selected from the colony and kept with mixed life stages of *T. putrescentiae* as their prey for 24 h. After this period, these well-fed females and males were starved for designated intervals (24, 48, 72, or 96 h) to produce starved predators.

To procure eggs, larvae, and protonymphs of *S. scimitus* for experiments, the gravid *S. scimitus* females were randomly selected from the stock colony and placed individually with *T. putrescentiae* mixed life stages as prey in the chamber of a Plexiglass cage for 20 h before commencing the trials. Since *S. scimitus* eggs and larvae are sensitive to dry conditions. To keep moisture, scotch tape was attached to tissue paper at the bottom of the cage. The cages with mites were kept in a desiccator at 25 ^{O}C, 85 ± 5% RH, and 16L:8D photoperiod in an incubator. The 20 h eggs obtained were collected and reared individually with *T. putrescentiae* mixed life stages as prey to obtain larvae, well-fed protonymphs, and well-fed deutonymphs. To obtain well-fed females and males, *S. scimitus* individuals were randomly selected from the colony and kept with mixed life stages of *T. putrescentiae* as their prey for 24 h.

Experimental procedure

The heterospecific predation and preference experiments were performed using a Plexiglass cage, in which a conical-shaped hole was drilled instead of a round hole (8 mm) (Jena et al. 2024, 2026a), and scotch tape was attached along with tissue paper at the bottom of the cage to keep it moist. The experimental cages were placed in a desiccator in an incubator maintained at 25°C, 85 ± 5% RH, and 16L/8D photoperiod.

Heterospecific predation of Blattisocius mali in the absence of alternative prey

All feeding developmental stages of *B. mali*, i.e., protonymph, deutonymph, adult female, or adult male, were used as predators, while the 20 h egg, 2 h larva, 4 h protonymph, 4 h deutonymph, and well-fed adult females and males of *S. scimitus* were used as heterospecific prey candidates. The effects of predator starvation, prey type, and predator type were examined (Table 1). One well-fed *B. mali* protonymph, deutonymph, adult female, or adult male was tested in combination with one well-fed *S. scimitus* protonymph, deutonymph, adult female, or adult male. Each well-fed or unfed *B. mali* protonymph or deutonymph was combined with either one 20 h egg or a 2 h larva of *S. scimitus* as prey. Each *B. mali* adult male, starved for 0, 24, or 48 h, was taken with either one 20 h egg or a 2 h larva of *S. scimitus*. Each *B. mali* adult female, starved for 0, 24, 48, 72, or 96 h, was tested with either one 20 h egg

or a 2 h larva of *S. scimitus*. Each predator-prey combination was replicated 30 times. Twenty hours after the start of the experiment, whether the heterospecific prey was preyed upon by predators was recorded.

Table 1
Predator-prey combinations used in the heterospecific predation experiments of *Blattisocius mali* in the absence of alternative prey.

Predator (*Blattisocius mali*)	**Heterospecific prey (*Stratiolaelaps scimitus*)**	**Number of replications (*n*)**
Well-fed protonymph	Well-fed protonymph, deutonymph, adult female, or adult male	30
Well-fed deutonymph	Well-fed protonymph, deutonymph, adult female, or adult male	30
Well-fed female	Well-fed protonymph, deutonymph, adult female, or adult male	30
Well-fed male	Well-fed protonymph, deutonymph, adult female, or adult male	30
0, 24, 48, 72, or 96 h-starved female	20 h egg	30
	2 h larva	30
0, 24, or 48 h starved male	20 h egg	30
	2 h larva	30
Well-fed or unfed protonymph	20 h egg	30
	2 h larva	30
Well-fed or unfed deutonymph	20 h egg	30
	2 h larva	30

Preference of Blattisocius mali to conspecific and heterospecific prey

All developmental stages of *B. mali* that ingest food (unfed protonymph, unfed deutonymph, 72 h starved adult female, or 24 h starved male) were used as predators, and the 20 h egg or 2 h larva of both *B. mali* (conspecifics) and *S. scimitus* (heterospecifics) were used as prey candidates. Since preliminary studies showed that 24 h- or 48 h-starved female *B. mali* did not choose either conspecific or heterospecific prey during the experimental period (12 or 24 h), 72 h-starved females were used. Each predator was provided with 3 eggs or larvae of both conspecifics and heterospecifics. Twenty-four hours after the start of the experiment, the number of conspecific and heterospecific eggs preyed upon by the predator was recorded. Twelve hours after the start of the experiment, the number of larvae preyed upon was noted due to the shorter developmental period of larvae. Each predator-prey combination was replicated 20 times.

Statistical analysis

The proportion of predators that consumed heterospecific prey among all tested predators of each type was analysed using a Generalised Linear Model (GLM) with a binomial distribution and a logit link function. Similarly, prey preference among different life stages of B. mali was assessed by comparing the proportions of conspecific and heterospecific prey consumed using a GLM with a binomial distribution and a logit link function. In both analyses, post hoc pairwise comparisons were performed using Tukey's adjustment for multiple comparisons. All statistical analyses were conducted using R software (R Core Team, 2025).

Results

Heterospecific predation of Blattisocius mali in the absence of alternative prey

All feeding developmental stages of *B. mali* ate eggs and larvae of *S. scimitus*. Only a very low proportion of *B. mali* females, specifically four out of thirty, were observed to kill *S. scimitus* protonymphs. The remaining *B. mali* females were killed by *S. scimitus* protonymphs. Conversely, all *B. mali* protonymphs, deutonymphs, and adult males were killed and eaten by *S. scimitus* protonymphs and more advanced developmental stages.

When examining the behaviour of *B. mali* females towards heterospecific prey, it was found that the mean proportion of *B. mali* females (out of all tested individuals) that ate heterospecific prey was significantly affected by the starvation period (χ^2 = 12.6, df = 4, $P < 0.05$) and prey type (χ^2 = 266.9, df = 1, $P < 0.0001$). However, there was no significant interaction between starvation period and prey type (χ^2 = 4.1, df = 4, $P = 0.39$). Specifically, the proportion of well-fed (i.e., 0 h starved) *B. mali* females that ate heterospecific larvae was similar to that of 24 h starved females ($P > 0.05$), but it was significantly lower than that of *B. mali* females starved for 48 h or longer ($P < 0.05$) (Fig. 1). Conversely, the proportion of *B. mali* adult females that ate heterospecific eggs was similar among starvation periods ($P > 0.05$). Additionally, the proportion of *B. mali* females that ate heterospecific larvae was significantly higher than that of those females that ate heterospecific eggs ($P < 0.05$) (Fig. 1).

When assessing the behaviour of *B. mali* females or males towards heterospecific prey, it was observed that the proportion of *B. mali* consuming heterospecific eggs was significantly affected by the starvation period (χ^2 = 7.2, df = 2, $P < 0.05$). However, neither the predator sex (χ^2 = 2.2, df = 1, $P = 0.13$) nor the interaction between the starvation period and predator sex (χ^2 = 0.2, df = 2, $P = 0.90$) showed a significant effect. In contrast, the proportion of *B. mali* individuals consuming heterospecific larvae was markedly affected by both the starvation period (χ^2 = 23.7, df = 2, $P < 0.0001$) and predator sex (χ^2 = 13.5, df = 1, $P < 0.001$), Yet, the interaction between these two factors remained non-significant (χ^2 = 1.5, df = 2, $P = 0.47$). The proportion of 0 h, 24 h, or 48 h starved *B. mali* males that ate heterospecific eggs or larvae was similar ($P > 0.05$) (Fig. 2). The proportion of *B. mali* males that ate heterospecific eggs was similar to that of females consuming the same prey ($P > 0.05$). Interestingly, the proportion of well-fed *B. mali*

males that ate heterospecific larvae was significantly higher than that of well-fed females consuming the same prey ($P < 0.05$). Conversely, the proportion of 24 h or 48 h starved *B. mali* males that ate heterospecific eggs was similar to that of 24 h or 48 h starved females consuming the same prey ($P > 0.05$) (Fig. 2).

When the behaviour of various life stages of *B. mali* was tested towards heterospecific prey, the proportion of *B. mali* consuming heterospecific prey was significantly affected by the prey type ($\chi^2 = 59.2$, df = 1, $P < 0.0001$) and life stage of *B. mali* ($\chi^2 = 13.2$, df = 3, $P < 0.01$) as well as their interaction ($\chi^2 = 52.3$, df = 3, $P < 0.0001$) (Fig. 3). Notably, a much higher proportion of *B. mali* protonymphs consumed heterospecific eggs compared to deutonymphs, females, or males ($P < 0.05$) (Fig. 3). Conversely, the proportion of *B. mali* males consuming heterospecific larvae was significantly higher than that of *B. mali* females, deutonymphs, or protonymphs engaging in the same behaviour ($P < 0.05$) (Fig. 3). Furthermore, *B. mali* deutonymphs, females, or males showed a significantly higher tendency to prey on heterospecific larvae than on eggs ($P < 0.05$). In contrast, the proportion of *B. mali* protonymphs that ate heterospecific larvae was similar to that of those consuming heterospecific eggs ($P > 0.05$).

When the behaviour of *B. mali* immatures was evaluated towards heterospecific prey, it was noted that the proportion of *B. mali* immatures that ate heterospecific eggs was significantly influenced by the life stage ($\chi^2 = 14.0$, df = 1, $P < 0.001$). However, neither the starvation period ($\chi^2 = 3.3$, df = 1, $P = 0.06$) nor its interaction with the life stage ($\chi^2 = 0.02$, df = 1, $P > 0.05$) had a significant effect. In contrast, the proportion of *B. mali* immatures that ate heterospecific larvae was significantly affected by starvation ($\chi^2 = 35.5$, df = 1, $P < 0.0001$). Neither the life stage ($\chi^2 = 2.6$, df = 1, $P = 0.10$) nor its interaction with starvation ($\chi^2 = 0.4$, df = 1, $P = 0.99$) was significant. The proportion of unfed and fed protonymphs consuming heterospecific eggs did not differ significantly ($P > 0.05$) (Fig. 5). However, unfed protonymphs were significantly more likely to consume heterospecific larvae compared to fed protonymphs ($P < 0.05$). Similarly, unfed deutonymphs had a significantly higher rate of consuming heterospecific eggs than fed deutonymphs ($P < 0.05$), but there was no significant difference in larval consumption between unfed and fed deutonymphs ($P > 0.05$). Moreover, fed protonymphs showed a higher tendency to consume heterospecific eggs than fed deutonymphs ($P < 0.05$) (Fig. 5). Yet, the rates at which fed protonymphs and fed deutonymphs consumed heterospecific larvae did not differ significantly ($P > 0.05$). Finally, the proportions of unfed protonymphs and unfed deutonymphs consuming either heterospecific eggs or larvae were statistically similar ($P > 0.05$).

Preference of Blattisocius mali to conspecific and heterospecific prey

When examining the preference of various life stages of *B. mali* towards conspecific and heterospecific eggs, it was found that the proportion of eggs eaten was significantly affected by the prey type ($F = 87.5$, df = 1, $P < 0.0001$) and its interaction with predator life stage ($F = 25.4$, df = 3, $P < 0.0001$). However, the effect of predator life stage ($F = 2.7$, df = 3, $P = 0.44$) was nonsignificant. All life stages of *B. mali* ate a significantly higher proportion of conspecific eggs than heterospecific ones ($P < 0.05$). Notably, across life stages, *B. mali* females consumed the highest proportion of heterospecific eggs.

When assessing the preference of various life stages of *B. mali* towards conspecific and heterospecific larvae, it was observed that the proportion of larvae eaten was significantly affected by the prey type (F = 112.1, df = 1, $P < 0.0001$) and its interaction with predator life stage (F = 12.2, df = 3, $P < 0.01$). However, the effect of predator life stage (F = 4.3, df = 3, P = 0.23) was nonsignificant. All life stages of *B. mali* ate a significantly higher proportion of heterospecific larvae than conspecific ones ($P < 0.05$). All life stages of *B. mali* ate a similar proportion of conspecific or heterospecific larvae ($P > 0.05$).

Discussion

The results of the current study revealed that the propensity of *B. mali* females to eat heterospecific eggs was not significantly affected by the starvation period. However, their propensity to eat heterospecific larvae increased with starvation periods up to 48 h, after which it plateaued. Across all starvation periods tested, *B. mali* females, males, or deutonymphs showed a greater propensity to feed on heterospecific larvae than on eggs. Notably, a similar proportion of *B. mali* males ate heterospecific eggs as females, but when it came to larvae, the proportion of well-fed males was higher than that of females. Furthermore, the proportion of *B. mali* protonymphs consuming heterospecific eggs was substantially higher than that of deutonymphs, females, or males. Additionally, the proportion of *B. mali* males that ate heterospecific larvae was significantly higher than that of *B. mali* females, deutonymphs, or protonymphs. All life stages of *B. mali* clearly discriminated between conspecific and heterospecific eggs or larvae. They preferred to prey upon conspecific eggs and heterospecific larvae when given a choice between conspecific and heterospecific eggs or larvae.

Interactions among predator species can significantly influence predator development and population stability. These relationships should be carefully considered when multiple species are introduced into an environment, especially in biological control scenarios where the disappearance of one species or the persistence of others can impact overall effectiveness (Rosenheim et al. 1995; Schausberger and Walzer 2001). Moreover, to safeguard native fauna, it is crucial to thoroughly assess how introduced predators may interact with indigenous species before their release into agricultural settings. Released exotic predators may potentially outcompete native predators, leading to the exclusion or decline of native species (Brodeur and Rosenheim 2000; Gotoh et al. 2014). Understanding these interactions requires studying their effects on population dynamics through controlled laboratory experiments and real-world applications before making decisions about releasing multiple predator species into greenhouses or fields (Walzer and Schausberger 1999). Although heterospecific predation of phytoseiid predators on other predatory mites, as well as their predation preference towards conspecific or heterospecific prey, have been extensively studied (Schausberger 1997; Schausberger 1999; Schausberger and Croft 1999; Walzer and Schausberger 1999; Negloh et al. 2012; Ghasemloo et al. 2016; Döker et al. 2021; Cai et al. 2026; Gong et al. 2026), there is no report on the heterospecific predation of a predatory soil mite on another predatory soil mite sharing similar prey and habitat, as well as its predation preference for conspecific or heterospecifics.

Our study demonstrated that the starvation period of *B. mali* affected the intensity of heterospecific predation across all developmental stages. This finding aligns with the results of Jena et al. (2026c), who observed that prolonged starvation periods led to increased predation rates of *B. mali* on its own immature forms. Due to difficulty in penetrating egg membranes, some predatory mite eggs are less vulnerable to predation than larvae (Schausberger and Croft 2000; Meszaros et al. 2007; Farazmand et al. 2015; Jena et al. 2026c). Similar results were obtained in the present study; Across all life stages, a greater proportion of *B. mali* attacked heterospecific larvae than eggs. These results may be explained by the active, random search behaviour of *B. mali.* Since eggs are smaller and immobile, the probability of randomly encountering them is lower, leading predators to more frequently prey upon the larger, mobile larvae. Ghasemloo et al. (2016) also reported that both *Phytoseiulus persimilis* (Athias-Henriot) and *Typhlodromus bagdasarjani* (Wainstein and Arutunjan) have higher predation rates on their larvae compared to eggs and protonymphs.

Contrary to our initial hypothesis, a similar or greater proportion of *B. mali* males attacked heterospecific prey than that of females did. The heterospecific eggs might have had a thick membrane and thus were not as favourable prey for both *B. mali* females and males in their larval stage. So, both females and males attacked a very small and similar number of heterospecific eggs. Jena et al. (2026c) showed that *B. mali* females did not experience immediate hunger as males do and usually started feeding after being starved for longer than males. This difference in hunger levels may explain why a lower proportion of well-fed females attacked heterospecific larvae compared to well-fed males. However, when females were subjected to prolonged starvation, 24 h or longer, their proportion was the highest and the same as that of males.

Heterospecific predation typically relates to differences in predator and prey characteristics, such as predator size, developmental stage, and prey size. Smaller, stationary, or less mobile individuals are generally more vulnerable and more likely to be preyed upon than larger, mature, or more active ones (Polis et al. 1989; Rosenheim et al. 1995; Gu et al. 2024). Contrary to the initial hypothesis, this study showed that *B. mali* protonymphs exhibited a higher predation rate on eggs, whereas males showed a greater tendency to prey on larvae. Although *B. mali* protonymphs became hungry more quickly than other life stages, *S. scimitus* larvae were bigger in size than *B. mali* protonymphs and thus less prone to predation compared to eggs. This size difference results in a lower heterospecific predation rate of *B. mali* protonymphs towards larvae.

Our study supports the hypothesis that *B. mali* could differentiate between conspecific and heterospecific larvae, showing a preference for preying on heterospecific larvae. This behaviour might be linked to the predation type of generalist predators (Schausberger 1999; Walzer and Schausberger 1999). Several generalist phytoseiid mites, including *Typhlodromus athiasae* (Porath and Swirskii), *T. pyri* (Scheuten), *T. swirskii* (Athias-Henriot), *T. phialatus* (Athias Henriot), *T. exhilaratus* (Ragusa), *T. bagdasarjani* (Wainstein & Arutunjan), *Kampimodromus aberrans* (Oudemans), *Euseius scutalis* (Athias Henriot), *Amblyseius degenerans* (Berlese), *N. californicus* (McGregor), and *N. fallacis* (Garman) exhibited discrimination ability showing a clear preference for preying on heterospecifics (Yao and Chant 1989;

Schausberger 1997; Schausberger 1999; Walzer and Schausberger 1999; Meszaros et al. 2007; Momen and Abdel Khalek 2009; Ghasemloo et al. 2016). Contrary to our initial expectation, the study showed that *B. mali* preferred to prey on conspecific eggs when given a choice between conspecific and heterospecific eggs. This preference might be influenced by the structural characteristics of the eggs, specifically the thick chorion of *S. scimitus*, or the lower nutritional value of heterospecific eggs, which could make these eggs less suitable or more difficult for *B. mali* to prey upon.

In summary, this study shows that *B. mali* can interact with *S. scimitus* and feed on *S. scimitus* eggs and larvae, potentially affecting pest biological control. Additionally, it shows that *B. mali* prefers conspecific eggs over heterospecific eggs and heterospecific larvae over conspecific larvae. Further studies are necessary to investigate the survival, development, and reproduction of *B. mali* on *S. scimitus* larvae as well as to assess the predation behaviour of *S. scimitus* on *B. mali*.

Declarations

Competing interests

No competing interests exist

Funding statement

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Author Contribution

M.K.J. and K.M. conceptualized the research; M.K.J. designed the methodology; M.K.J. performed the experiment; M.K.J. and M.S. analysed the data; M.K.J. prepared the initial draft of the Manuscript; M.K.J., K.M., and M.S. reviewed and edited the manuscript; K.M. supervised the research. All authors have read and approved the manuscript.

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Data Availability

The data used in this study are available by email request to the corresponding author, M.K.J. (jenamanoj401@gmail.com).

References

1. Abbas AA, Yassin EMA, El-Bahrawy AF, El-Sharabasy HM, Kamel MS (2020) Biology of *Blattisocius mali* (Oudemans) (Acari: Gamasida: Ascidae) feeding on different diets under laboratory conditions. EVMSPJ 16:92–101
2. Asgari F, Safavi SA, Sarraf-Moayeri H (2023) An investigation on demographic parameters of the predatory mite *Blattisocius mali* (Blattisociidae) fed on eggs of the fungus gnat *Lycoriella auripila* (Sciaridae). Plant Pest Res 13(1):1–14
3. Brødsgaard HF, Sardar MA, Enkegaard A (1996) Prey preference of *Hypoaspis miles* (Berlese) (Acarina: Hypoaspididae): Non-interference with other beneficials in glasshouse crops. IOBC/. WPRS Bull 19:23–26
4. Cai W, Fu XT, Dong XT, Zhang SL, Meng RX (2026) Alternative pollen diets modulate cannibalism in two phytoseiid mites (*Neoseiulus agrestis* and *Neoseiulus barkeri*). Syst Appl Acarol 19:943–955. https://doi.org/10.11158/saa.31.6.5
5. Castilho RC, de Moraes GJ, Silva ES, Freire RA, Da Eira FC (2009) The predatory mite *Stratiolaelaps scimitus* as a control agent of the fungus gnat *Bradysia matogrossensis* in commercial production of the mushroom *Agaricus bisporus*. Int J Pest Manag 55(3):181–185. https://doi.org/10.1080/09670870902725783
6. Chi H, Xie L, Zhang ZQ (2026) Functional responses and diet-dependent fecundity of *Stratiolaelaps scimitus* (Acari: Laelapidae) preying on western flower thrips pupae (Thysanoptera: Thripidae). J Insect Biodivers 78(1):45–60. https://doi.org/10.12976/jib/2026.78.1.8
7. Chi Y, Yu C, Zhu Y, Shu K, Gong Y, Yang H, Nong N, Zhao Z, Feng M, Li M, Chen Y (2026) Impact of intraguild predation between *Neoseiulus barkeri* and *Lasioseius scapulatus* on thrips control in cowpea. J Pest Sci 99(3):86. https://doi.org/10.1007/s10340-026-02045-x
8. Döker İ, Revynthi AM, Kazak C, Carrillo D (2021) Interactions among exotic and native phytoseiids (Acari: Phytoseiidae) affect biocontrol of two-spotted spider mite on papaya. Biol Control 163:104758. https://doi.org/10.1016/j.biocontrol.2021.104758
9. Elgar MA, Crespi BJ (1992) Ecology and evolution of cannibalism. In: Elgar MA, Crespi BJ (eds) Cannibalism: Ecology and evolution among diverse taxa. Oxford University Press, New York, pp 1–12
10. Enkegaard A, Sardar M, Brødsgaard H (1997) The predatory mite *Hypoaspis miles*: Biological and demographic characteristics on two prey species, the mushroom sciarid fly, *Lycoriella solani* and the mould mite, *Tyrophagus putrescentiae*. Entomol Exp Appl 82:135–146. https://doi.org/10.1046/j.1570-7458.1997.00123.x
11. Farazmand A, Fathipour Y, Kamali K (2015) Intraguild predation among *Scolothrips longicornis* (Thysanoptera: Thripidae), *Neoseiulus californicus* and *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) under laboratory conditions. Insect Sci 22:263–272. https://doi.org/10.1111/1744-7917.12047

12. Ghasemloo Z, Pakyari H, Arbab A (2016) Cannibalism and intraguild predation in the phytoseiid mites *Phytoseiulus persimilis* and *Typhlodromus bagdasarjani* (Acari: Phytoseiidae). Int J Acarol 42(3):149 – 52. https://doi.org/10.1080/01647954.2016.1141983
13. Gong Y, Zhang K, Xuan Q, Zhang ZQ (2026) Cannibalism in *Buchananiella whitei* (Hemiptera: Anthocoridae) and its intraguild interactions with seven predatory mites (Acari: Phytoseiidae and Laelapidae). https://doi.org/10.1002/ps.71042. Pest Manag Sci
14. Gu X, Zhang K, Zhang ZQ (2024) Interspecific interactions between two predatory mites of the mould mite *Tyrophagus putrescentiae* Schrank (Acari: Acaridae), a serious pest of stored products. J Stored Prod Res 105:102255. https://doi.org/10.1016/j.jspr.2024.102255
15. Hurd LE, Eisenberg RM (1990) Arthropod community responses to manipulation of a bitrophic predator guild. Ecology 71:2107–2114. https://doi.org/10.2307/1938624
16. Janssen A, Montserrat M, HilleRisLambers R, de Ross AM, Pallini A, Sabelis MW (2006) Intraguild predation usually does not disrupt biological control. In: Brodeur J, Boivin G (eds) Trophic and guild interactions in biological control. Springer, Netherlands, pp 21–44
17. Jena MK, Michalska K, Studnicki M (2024) The impact of humidity on the functional response of *Blattisocius mali* (Acari: Blattisociidae) preying on the acarid mite *Tyrophagus putrescentiae*. Sci Rep 14:28051. https://doi.org/10.1038/s41598-024-78997-w
18. Jena MK, Studnicki M, Michalska K (2025a) Functional response of different life stages of predatory mite *Blattisocius mali* preying on acarid mite. Tyrophagus putrescentiae Syst Appl Acarol 30(1):181–195. https://doi.org/10.11158/saa.30.1.13
19. Jena MK, Studnicki M, Michalska K (2025b) Effect of the ages of females and males of *Blattisocius mali* (Mesostigmata: Blattisociidae) on their functional response while preying on the acarid mite *Tyrophagus putrescentiae* (Sarcoptiformes: Acaridae). Int J Acarol 51(6):448–455. https://doi.org/10.1080/01647954.2025.2552207
20. Jena MK, Studnicki M, Michalska K (2026a) Effect of temperature on life table parameters of the predatory soil mite *Blattisocius mali* (Acari: Blattisociidae) fed on *Tyrophagus putrescentiae* (Acari: Acaridae). https://doi.org/10.1038/s41598-026-66347-x. Sci Rep
21. Jena MK, Studnicki M, Michalska K (2026b) Efficacy of *Blattisocius mali* (Acari: Blattisociidae) against *Tyrophagus putrescentiae* (Acari: Acaridae) on cucumber plants. J Plant Prot Res (In
22. Jena MK, Studnicki M, Michalska K (2026c) Cannibalism in the predatory soil mite Blattisocius mali (Acari: Blattisociidae) and its survival on the conspecific prey. Syst Appl Acarol (Pre-print)
23. Jena MK, Studnicki M, Sochacki D, Michalska K (2026d) Evaluation of the predatory soil mite *Blattisocius mali* (Acari: Blattisociidae) as a biocontrol agent of the acarid mite *Tyrophagus putrescentiae* (Acari: Acaridae) infesting bulbs. BioControl 1–13. https://doi.org/10.1007/s10526-026-10395-9
24. Liu M, Wang M, Yuan L, Chu W, Liu H, Li Y (2026) Intraguild predation alters life histories in *Neoseiulus barkeri* and *Scolothrips takahashii*: Asymmetric effects on development and reproduction. Pest Manag Sci 82(6):5767–5779. https://doi.org/10.1002/ps.70678

25. Loosey JE, Denno RF (1999) Factors facilitating synergistic predation: the central role of synchrony. Ecol Appl 9:378–386. https://doi.org/10.1890/1051-0761(1999)009[0378:FFSPTC]2.0.CO;2
26. McMurtry JA, Croft BA (1997) Life-styles of phytoseiid mites and their roles in biological control. Annu Rev Entomol 4242:291–321. https://doi.org/10.1146/annurev.ento.42.1.291
27. McMurtry JA, de Moraes GJ, Sourasso NA (2013) Revision of the lifestyles of Phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. Syst Appl Acarol 18:297–320. https://doi.org/10.11158/saa.18.4.1
28. Mendel D, Schausberger P (2011) Diet-dependent intraguild predation between the predatory mites *Neoseiulus californicus* and *Neoseiulus cucumeris*. J Appl Entomol 135:311–319. https://doi.org/10.1111/j.1439-0418.2010.01548.x
29. Meszaros A, Tixier MS, Cheval B, Barbar Z, Kreiter S (2007) Cannibalism and intraguild predation in *Typhlodromus exhilaratus* and *Typhlodromus phialatus* (Acari: Phytoseiidae) under laboratory conditions. Exp Appl Acarol 41:37–43. https://doi.org/10.1007/s10493-006-9046-x
30. Michalska K, Jena MK, Mrowińska A, Nowakowski P, Maciejewska D, Ziółkowska K, Studnicki M, Wit M (2023) Preliminary studies on the predation of the mite *Blattisocius mali* (Acari: Blattisociidae) on various life stages of spider mite, thrips and fruit fly. Insects 14:747. https://doi.org/10.3390/insects14090747
31. Michalska K, Jena MK, Studnicki M (2025) Effect of temperature on functional response of *Blattisocius mali* (Acari: Blattisociidae) preying on the acarid mite *Tyrophagus putrescentiae*. Sci Rep 15(1):15457. https://doi.org/10.1038/s41598-025-00268-z
32. Momen F, Abdel-Khalek A (2009) Cannibalism and intraguild predation in the phytoseiid mites *Typhlodromus swirskii*, *Euseius scutalis* and *Typhlodromus athiasae* (Acari: Phytoseiidae). Acarina 17:223–229. https://elib.utmn.ru/jspui/handle/ru-tsu/12722
33. Moran MD, Rooney TP, Hurd LE (1996) Top-down cascade from a biotrophic predator in an old-field community. Ecology 77:2219–2227. https://doi.org/10.2307/2265715
34. Moreira GF, de Moraes GJ (2015) The potential of free-living laelapid mites (Mesostigmata: Laelapidae) as biological control agents. In: Carillo D, de Moraes G, Pena J (eds) Prospects for biological control of plant-feeding mites and other harmful organisms. Progress in biological control, vol 19. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-319-15042-0_3
35. Navarro-Campos C, Wäckers FL, Pekas A (2016) Impact of factitious foods and prey on the oviposition of the predatory mites *Gaeolaelaps aculeifer* and *Stratiolaelaps scimitus* (Acari: Laelapidae). Exp Appl Acarol 70:69–78. https://doi.org/10.1007/s10493-016-0061-2
36. Negloh K, Hanna R, Schausberger P (2012) Intraguild predation and cannibalism between the predatory mites *Neoseiulus neobaraki* and *N. paspalivorus*, natural enemies of the coconut mite *Aceria guerreronis*. Exp Appl Acarol 58(3):235–246. https://doi.org/10.1007/s10493-012-9581-6
37. Polis GA, Holt RD (1992) Intraguild predation: the dynamics of complex trophic interactions. Trends Ecol Evol 7(5):151–154. https://doi.org/10.1016/0169-5347(92)90208-S

38. Polis GA, Myers CA, Holt RD (1989) The ecology and evolution of intraguild predation: potential competitors that eat each other. Annu Rev Ecol Syst 20:297–330. http://www.jstor.org/stable/2097094
39. R Core Team (2025) R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria. https://www.r-project.org/
40. Rosenheim JA, Kaya HK, Ehler LE, Marois JJ, Jaffee BA (1995) Intraguild predation among biological control agents: theory and evidence. Biol Control 5:303–335. https://doi.org/10.1006/bcon.1995.1038
41. Schausberger P (1997) Inter- and intraspecific predation on immatures by adult females in *Euseius finlandicus*, *Typhlodromus pyri* and *Kampimodromus aberrans* (Acari: Phytoseiidae). Exp Appl Acarol 21:131–150. https://doi.org/10.1023/A:1018478418010
42. Schausberger P (1999) Predation preference of *Typhlodromus pyri* and *Kampimodromus aberrans* (Acari: Phytoseiidae) when offered con- and heterospecific immature life stages. Exp Appl Acarol 23:389–398. https://doi.org/10.1023/A:1006172320540
43. Schausberger P, Croft BA (1999) Predation on and discrimination between con-and heterospecific eggs among specialist and generalist phytoseiid mites (Acari: Phytoseiidae). Environ Entomol 28(3):523–528. https://doi.org/10.1093/ee/28.3.523
44. Schausberger P, Croft BA (2000a) Cannibalism and intraguild predation among phytoseiid mites: are aggressiveness and prey preference related to diet specialization? Exp Appl Acarol 24(9):709–725. https://doi.org/10.1023/A:1010747208519
45. Schausberger P, Croft BA (2000b) Nutritional benefits of intraguild predation and cannibalism among generalist and specialist phytoseiid mites. Ecol Entomol 25(4):473–480. https://doi.org/10.1046/j.1365-2311.2000.00284.x
46. Schausberger P, Walzer A (2001) Combined versus single species release of predaceous mites: predator-predator interactions and pest suppression. Biol Control 20:269–278. https://doi.org/10.1006/bcon.2000.0908
47. Shakya S, Weintraub PG, Coll M (2009) Effect of pollen supplement on intraguild predatory interactions between two omnivores: the importance of spatial dynamics. Biol Control 50(3):281–287. https://doi.org/10.1016/j.biocontrol.2009.04.012
48. Sih A, Englund G, Wooster D (1998) Emergent impacts of multiple predators on prey. Trends Ecol Evol 13:325–329. https://doi.org/10.1016/S0169-5347(98)01437-2
49. Steiner M, Goodwin S, Wellham T (1999) A simplified rearing method for *Stratiolaelaps* (*Hypoaspis*) *miles* (Acari: Laelapidae). IOBC Bull 22:241–242
50. Tsuchida Y, Masui S, Kasai A (2022) Effects of intraguild predation and cannibalism in two generalist phytoseiid species on prey density of the pink citrus rust mite in the presence of high-quality food. Biocontrol 67:287–296. https://doi.org/10.1007/s10526-022-10139-5
51. Walzer A, Blümel S, Schausberger P (2001) Population dynamics of interacting predatory mites, *Phytoseiulus persimilis* and *Neoseiulus californicus*, held on detached bean leaves. Exp Appl Acarol

25:731–743. https://doi.org/10.1023/A:1016332129137

52. Walzer A, Schausberger P (1999) Predation preferences and discrimination between con- and heterospecific prey by the phytoseiid mites *Phytoseiulus persimilis* and *Neoseiulus californicus*. Biocontrol 43:469–478. https://doi.org/10.1023/A:1009974918500
53. Yadav T, Omkar, Mishra G (2026) Cannibalism in natural enemies. Behavior of Insect Natural Enemies. Ecology and Applications in Biological Control. Academic, pp 239–248. https://doi.org/10.1016/B978-0-443-24796-5.00008-3
54. Yano E (2005) Effects of intraguild predation and interspecific competition among biological control agents in augmentative biological control in greenhouses. Second International Symposium on Biological Control of Arthropods, Davos, Switzerland September 12–16, 2005, pp. 523–530
55. Yao DS, Chant DA (1989) Population growth and predation interference between two species of predatory phytoseiid mites (Acarina: Phytoseiidae) in interactive systems. Oecologia 80(4):443–455. https://doi.org/10.1007/BF00380065
56. Zhang K, Zhang ZQ (2022) Kin recognition by cannibals is modulated by hunger level in a generalist predatory mite *Amblyseius herbicolus* (Chant) (Acari: Phytoseiidae). J Appl Entomol 146(5):579–585. https://doi.org/10.1111/jen.12973

Figures

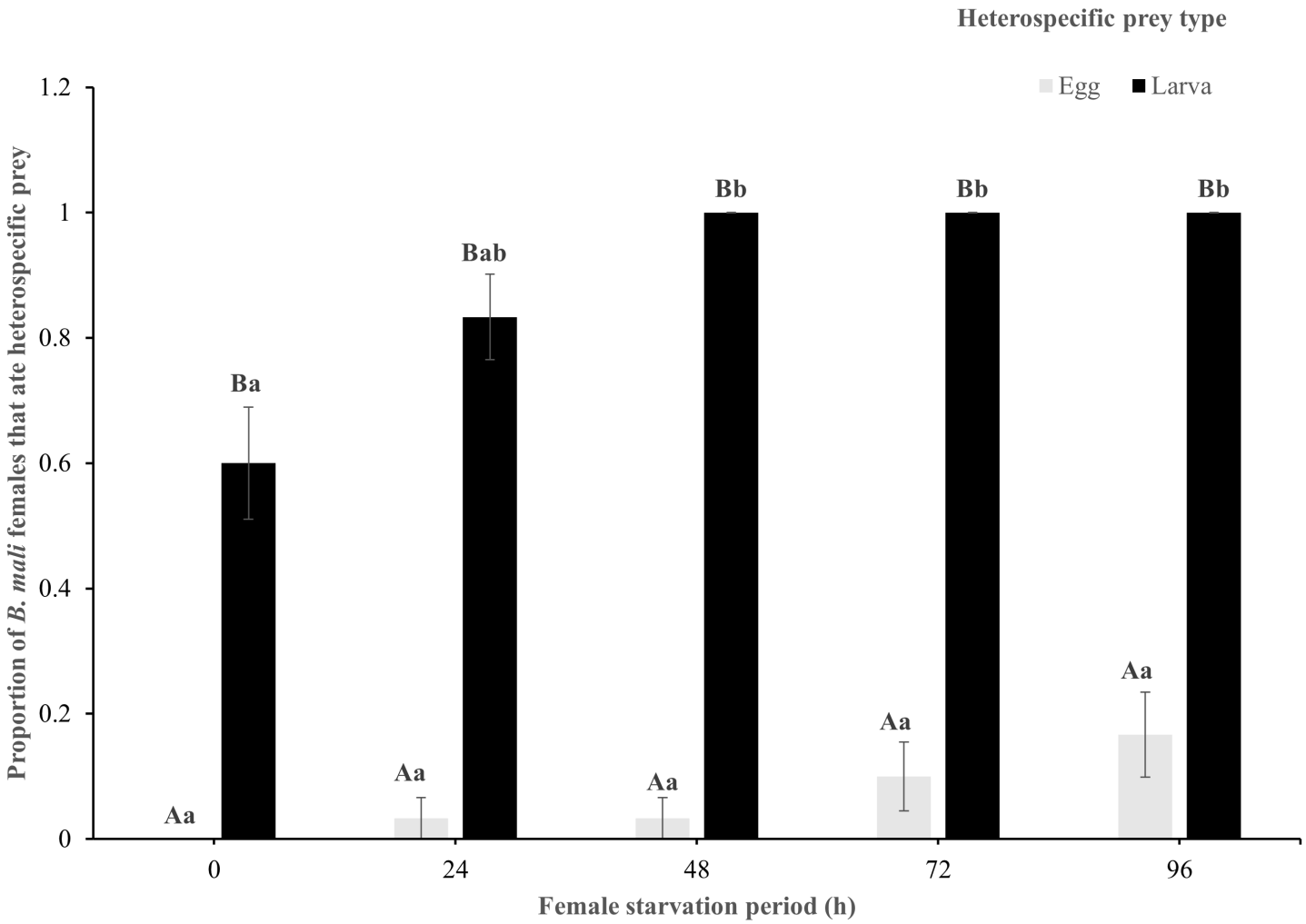


Figure 1

Mean (*±SE*) proportion of *Blattisocius mali* adult females (**n* =30), of the tested starvation periods, that ate heterospecific prey. Different uppercase letters indicate significant differences between prey types at each starvation period, while lowercase letters indicate significant differences among starvation periods of *B. mali* preying on the same prey ($P < 0.05$; Tukey test).

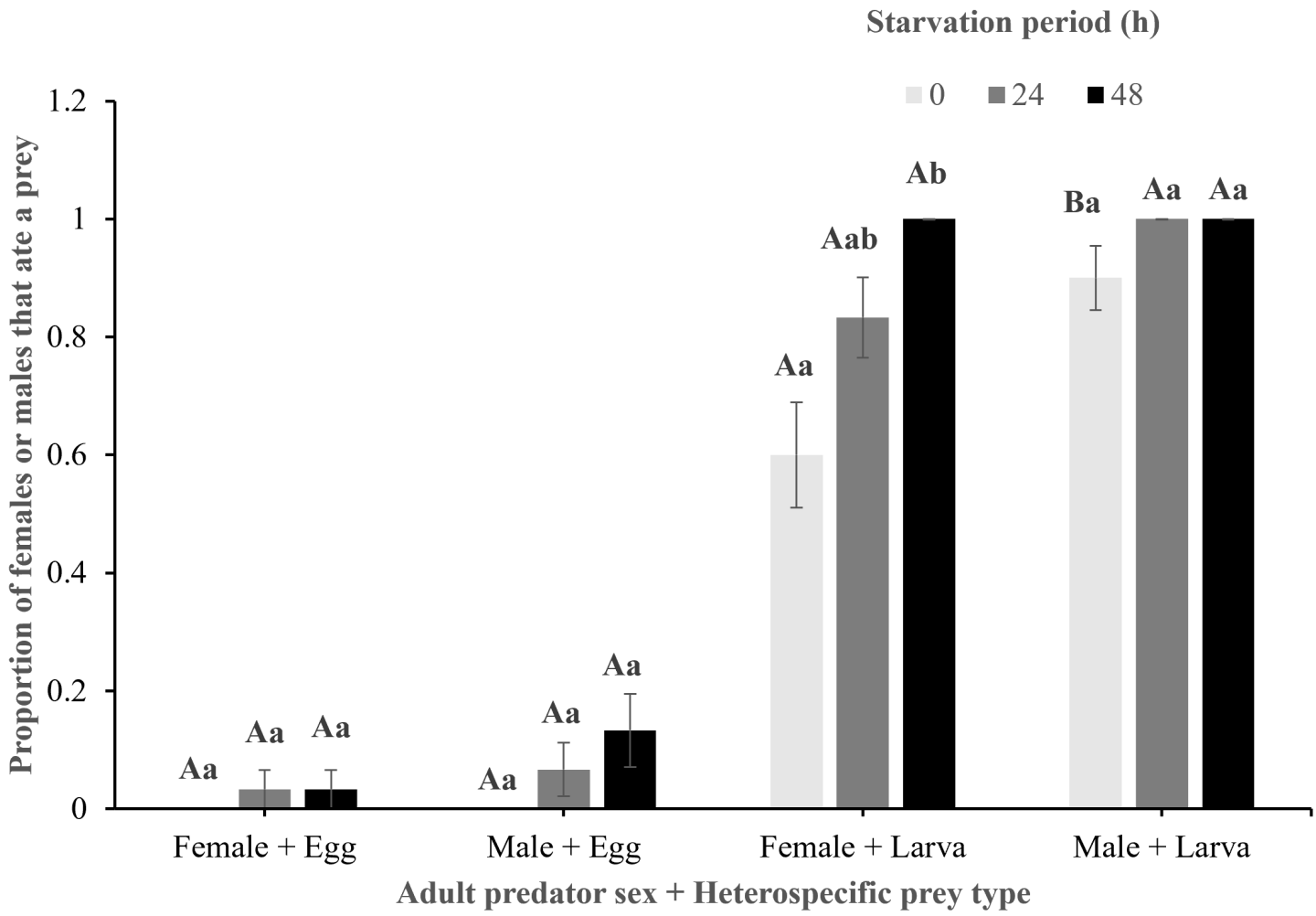


Figure 2

Mean (*±SE*) proportion of *Blattisocius mali* adult females or males (*n = 30), of various starvation periods, that ate heterospecific prey. Different uppercase letters indicate significant differences between female and male *B. mali* that ate the same prey, while lowercase letters indicate significant differences among starvation periods of female or male *B. mali* preying on the same prey ($P < 0.05$; Tukey test).

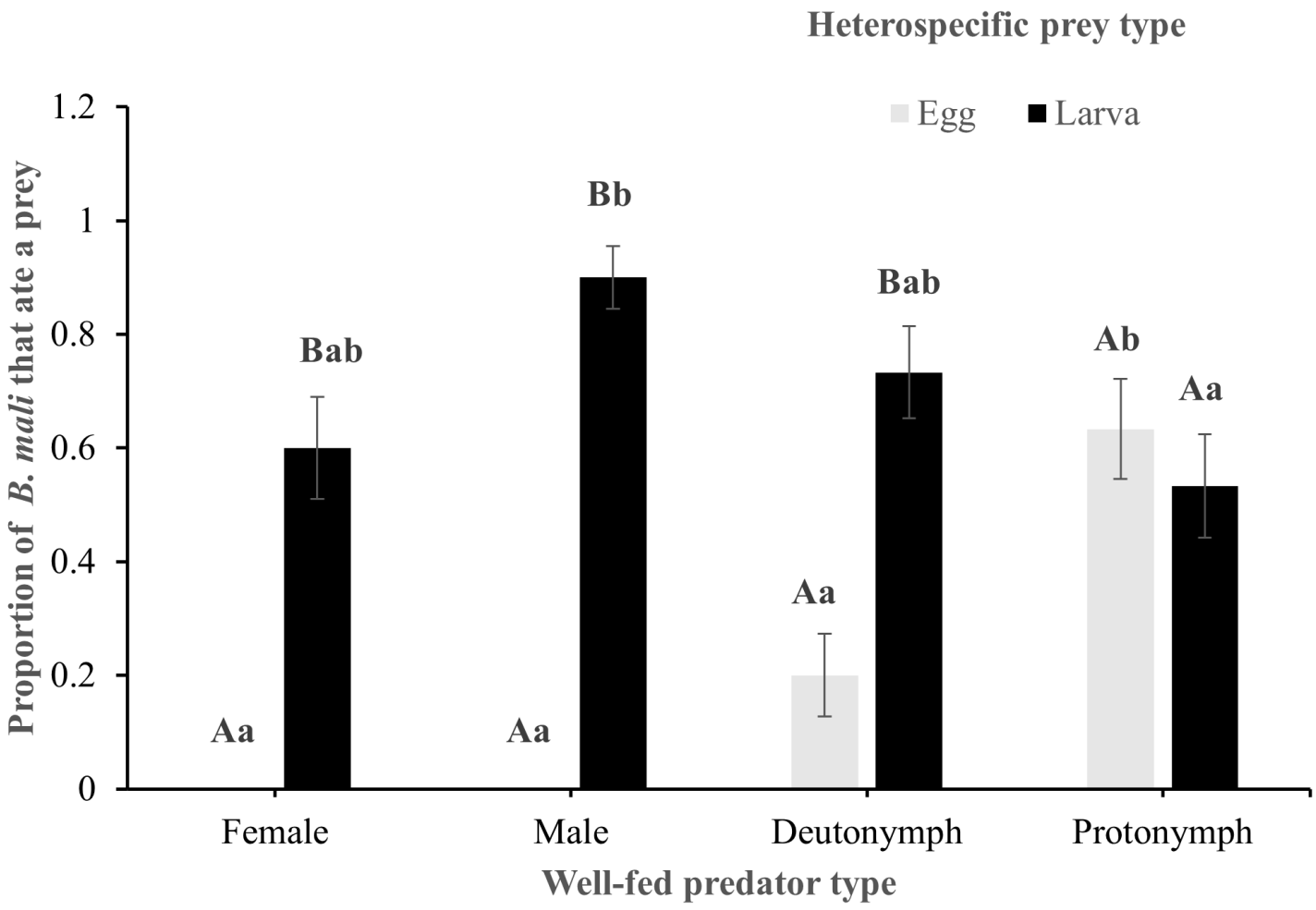


Figure 3

Mean (*±SE*) proportion of *Blattisocius mali* life stages (**n* = 30) that ate heterospecific prey. Different uppercase letters indicate significant differences between prey types eaten by each predator, while lowercase letters indicate significant differences among life stages of *B. mali* preying on the same prey ($P < 0.05$; Tukey test).

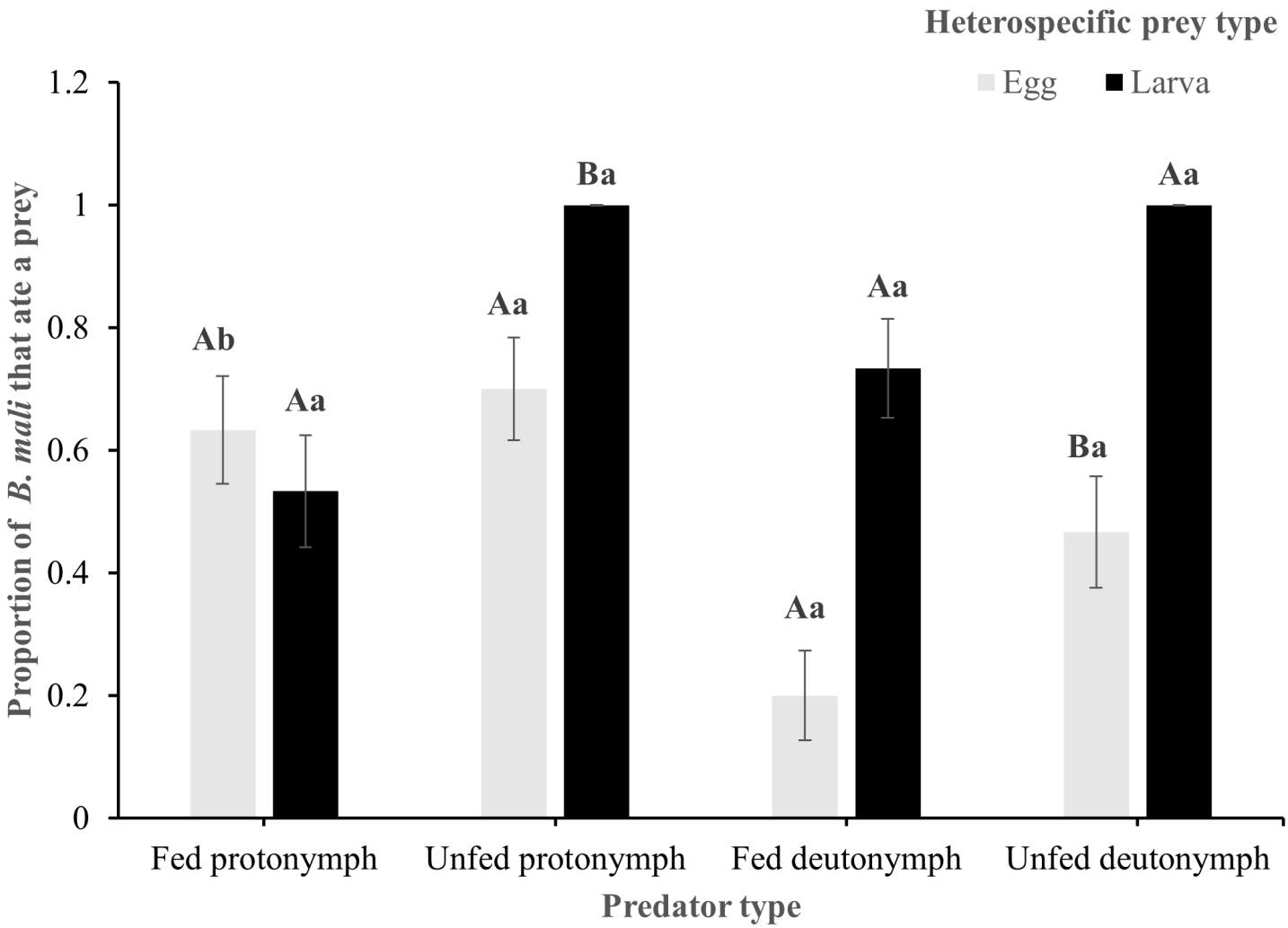


Figure 4

Mean (*±SE*) proportion of fed or unfed protonymph and deutonymph of *Blattisocius mali* (**n* = 30) that ate heterospecific prey. Different uppercase letters indicate significant differences between fed and unfed protonymph or deutonymph of *B. mali*preying on the same prey, while lowercase letters indicate significant differences between fed/unfed protonymph and deutonymph of *B. mali*preying on the same prey ($P < 0.05$; Tukey test).

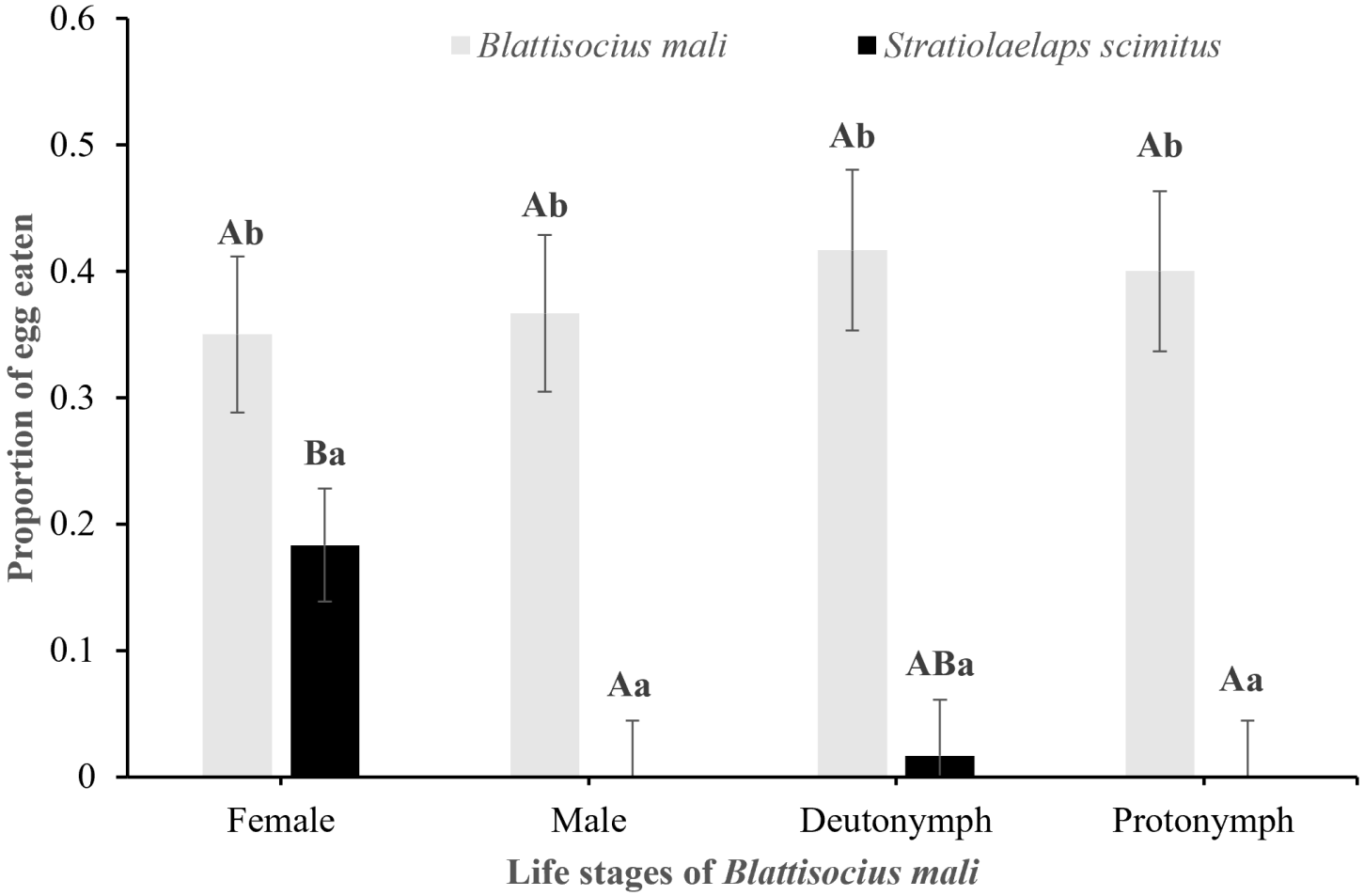


Figure 5

Mean (*±SE*) proportion of conspecific (*Blattisocius mali*) and heterospecific (*Stratiolaelaps scimitus*) eggs eaten by different life stages of *B. mali* (**n*= 20) held singly in Plexiglass cages for 24 h. Different uppercase letters indicate significant differences among life stages of *B. mali* that ate the same prey, while lowercase letters indicate significant differences between the proportion of conspecific and heterospecific eggs eaten by *B. mali* ($P < 0.05$; Tukey test).

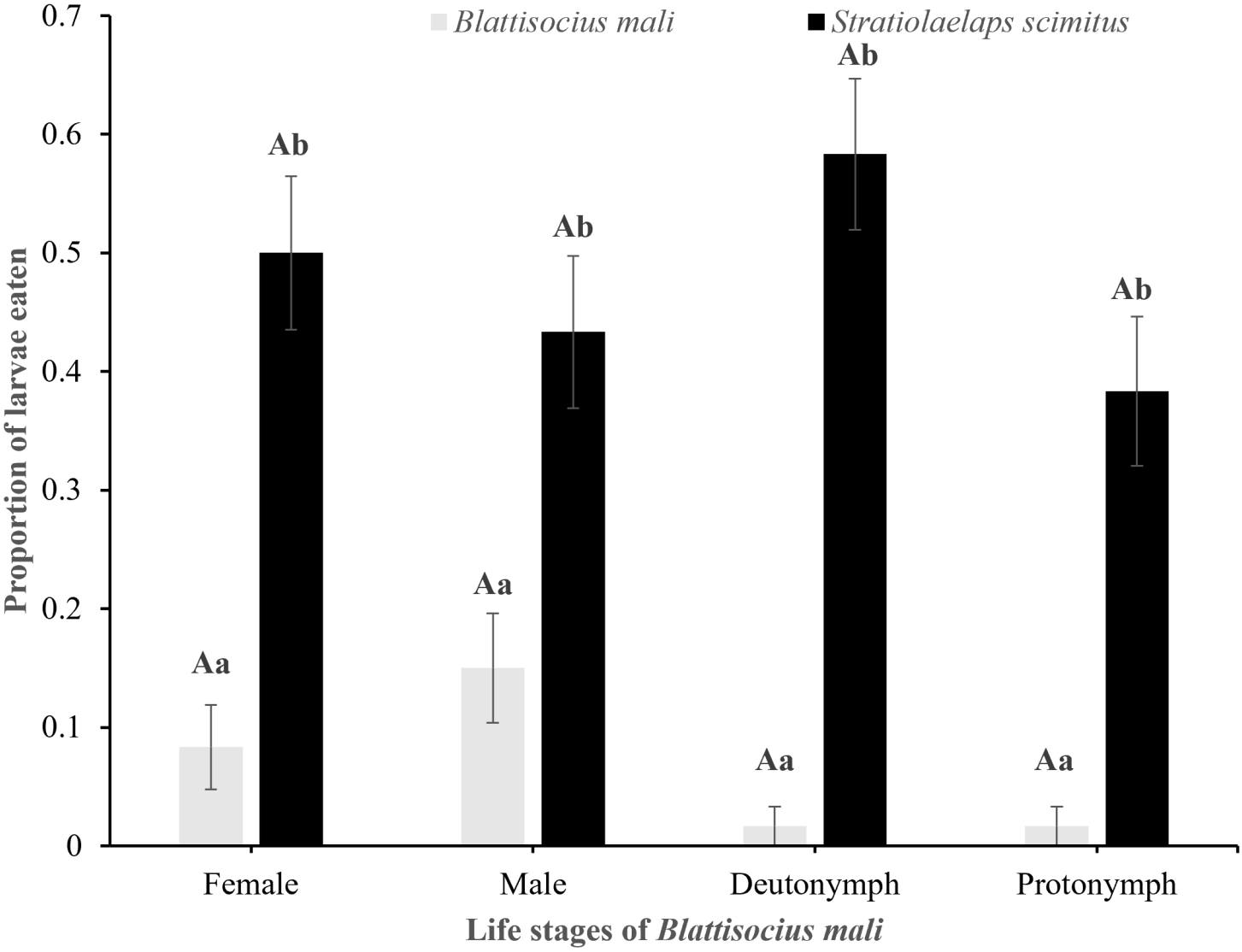


Figure 6

Mean (±*SE*) proportion of conspecific (*Blattisocius mali*) and heterospecific (*Stratiolaelaps scimitus*) larvae eaten by different life stages of *B. mali* (*n= 20) held singly in Plexiglass cages for 12 h. Different uppercase letters indicate significant differences among life stages of *B. mali* that ate the same prey, while lowercase letters indicate significant differences between the proportion of conspecific and heterospecific larvae eaten by *B. mali* ($P < 0.05$; Tukey test).