

Behavior and Predatory Ability of Several Predatory Insects at Different Prey Densities

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Abstract: Understanding predator behavior and predation capacity is essential for determining their potential as biological control agents. This study aimed to evaluate the searching time, handling time, and predation ability of three predators Syrphidae larvae, *Coccinella* sp. larvae, and *Curinus coeruleus* adults at different prey densities. Five prey-density treatments (5, 10, 15, 20, and 25 individuals) were tested using *Heteropsylla cubana* as prey for *C. coeruleus* and *Rhopalosiphum maidis* for Syrphidae and *Coccinella* sp. The results showed that increasing prey density significantly shortened the searching time of all predators. *C. coeruleus* demonstrated the fastest searching ability, followed by Syrphidae and *Coccinella* sp. Handling time also varied among predators, with *C. coeruleus* requiring the shortest time due to its chewing-type mouthparts, compared with the piercing–sucking mouthparts of Syrphidae and *Coccinella* sp. Predation capacity differed across predators; only *C. coeruleus* successfully consumed all prey at every density within 6 hours, while the other predators reached satiation at higher densities. Overall, *C. coeruleus* exhibited the highest efficiency across all parameters, indicating its strong potential as an effective biological control agent. Increasing prey density consistently enhanced predation activity, highlighting the importance of prey availability in predator effectiveness.

Keywords: Biological control; Predator behavior; Prey density; *Curinus coeruleus*; Predation ability.

Introduction

Biological control is an important component of sustainable pest management in agricultural ecosystems. The use of natural enemies to regulate pest populations has become increasingly important as an environmentally friendly alternative to chemical pesticides. Natural enemies, including predators, parasitoids, and pathogens, play a vital role in sustaining ecological balance by reducing pest populations and preventing outbreaks that could

lead to substantial crop losses (Bale et al., 2008; van Lenteren, 2012; Gurr et al., 2017; Heimpel & Mills, 2017). Among these natural enemies, predators are widely recognized for their ability to directly reduce pest abundance through predation activities.

The interaction between predators and their prey constitutes one of the fundamental concepts in ecological studies. Predator prey dynamics play a significant role in shaping the structure and stability of biological communities and influence the effectiveness of natural

enemies as biological control agents. Several ecological characteristics determine the performance of predators in controlling pest populations, including their searching efficiency, prey handling time, and predation capacity. Searching time is defined as the duration required for a predator to locate its prey, whereas handling time refers to the period needed to capture, immobilize, and consume the prey. These behavioral traits are strongly associated with the functional response of predators and provide essential insights for assessing their effectiveness in biological control programs (Radiyahanto et al., 2015).

Furthermore, predators may adjust their foraging behavior depending on prey availability, as prey density can influence predator efficiency and feeding activity (Williams & Flaxman, 2012). Various predator species are commonly found in agricultural ecosystems and play a crucial role in suppressing pest populations. For instance, members of the family Coccinellidae are widely recognized as effective predators of several pest species, including aphids, whiteflies, and mealybugs (Solomon, 1975; Silva et al., 1992). In vegetable cropping systems, predators such as *Coccinella transversalis* and *C. coeruleus* are frequently encountered and contribute to natural pest regulation. In particular, *C. coeruleus* has been reported as an important predator of jumping plant lice such as *H. cubana* and *Diaphorina citri* (Hodek & Honěk, 2009). Despite the presence of these predators in many agricultural habitats, information regarding their behavioral characteristics and predation performance under different prey densities remains limited.

Previous studies have mainly focused on the predatory capacity of certain coccinellid species against specific pest insects. However, comparative information regarding the behavioral characteristics of different predators, particularly in terms of prey searching time, prey handling time, and predation ability under varying prey densities, is still insufficient. Such information is important to better understand predator efficiency and to identify potential biological control agents that can be effectively utilized in integrated pest management strategies. Based on Jachowicz et al. (2025), one of the behaviors closely associated with the predatory potential of insects is feeding behavior, which

determines their capacity to efficiently locate, capture, and consume prey. The feeding and foraging behavior of predators strongly influences predation efficiency and their effectiveness in biological control programs.

Therefore, this study was conducted to assess the behavioral characteristics and predatory capacity of three predators Syrphidae larvae, *Coccinella* sp. larvae, and adult *C. coeruleus* under different prey density levels. Specifically, this research analyzed the searching time, handling time, and predation capacity of these predators toward their respective prey, *H. cubana* and *R. maidis*.

Materials and Methods

Time and Location

The research was conducted in March 2022 at the Biological Control Laboratory, Department of Plant Protection, IPB University, Dramaga, Bogor, West Java, Indonesia.

Materials

The tools used were petri dishes, a small brush, a mounted needle, a stopwatch, writing tools (pen and notebook), a microscope, and a camera. The materials used were Syrphidae larvae, *C. coeruleus* adults, *Coccinella* sp. larvae, the leucaena psyllid *H. cubana*, and the maize aphid *R. maidis*.

Research Procedures

Preparation

Prepare a 15 cm diameter Petri dish as a test arena for each pair of predator adults and fourth-instar prey larvae. Ensure that the predators are in a hungry condition (fasted for 12–24 hours) to stimulate hunting activity. Also prepare prey with different densities according to the treatments.

Procedure

Five prey-density treatments were prepared by introducing 5, 10, 15, 20, and 25 prey individuals. *Curinus* predators were provided with *H. cubana* prey, whereas *Coccinella* and Syrphidae predators were provided with *R. maidis* prey. Each treatment was replicated three times. A single predator individual was subsequently introduced into each Petri dish containing prey, according to the type

and density treatments being tested. Observe the duration of the search time until the predator captures its first prey (from the moment the predator is introduced into the Petri dish until it captures the prey) and the second prey. The time required by the predator to consume the first and second prey items was recorded. The number of remaining prey individuals was then documented after 1, 3, 6, and 24 hours of observation.

Results and Discussion

Prey Searching Time

The results of the observations indicated that prey density significantly influenced the searching time of the predator. Higher prey densities resulted in shorter periods required for

the predator to locate its prey. This pattern was evident in both the search time for the first prey (Figure 1A) and the second prey (Figure 1B). The order of predators from the fastest to the slowest in finding both the first and second prey was *C. coeruleus*, Syrphidae, and *Coccinella* sp.

The results of the study indicated that prey density had a significant effect on the duration of prey searching. The higher the prey density, the shorter the time required by the predators to locate their prey. This pattern was evident in both the search time for the first prey (Figure 1A) and the second prey (Figure 1B). The order of predators from the fastest to the slowest in locating the first and second prey was *C. coeruleus*, Syrphidae, and *Coccinella* sp.

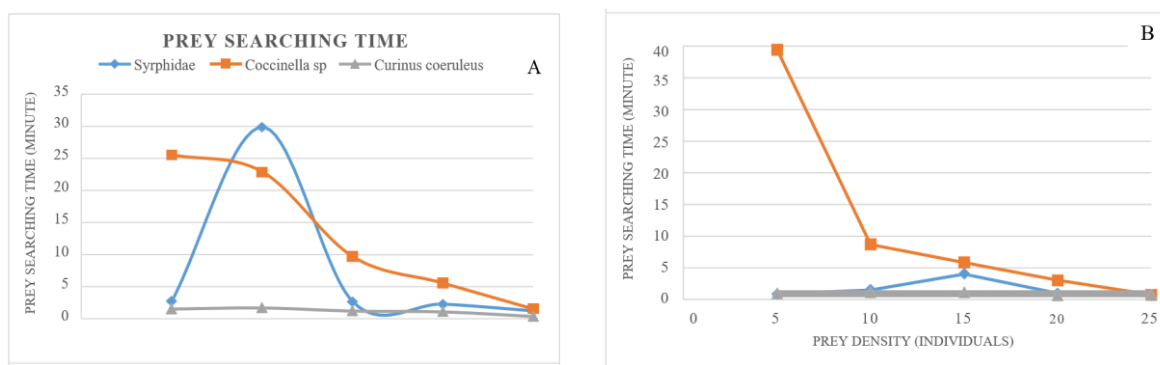


Figure 1. Effect of Prey Density on the Prey Searching Time of Several Predators (Syrphidae, *Coccinella* sp., and *C. coeruleus*) for the First Prey (A) and the Second Prey (B)

For the search time of the first prey, the predators *C. coeruleus* and Syrphidae located their prey more quickly (in less than 5 minutes) than *Coccinella* sp. at prey densities of 5, 10, 15, and 20 individuals, although Syrphidae at the density of 10 prey required a much longer time, namely 30 minutes. At the prey density of 25 individuals, all predators required less than 5 minutes to locate their prey. Similarly, for the search time of the second prey, *C. coeruleus* and Syrphidae were faster (less than 20 minutes) in locating their prey than *Coccinella* sp. at prey densities of 5, 10, and 15 individuals. At prey densities of 20 and 25 individuals, all predators required less than 20 minutes to locate their prey.

Handling Time

Each predator tested, both at low and high prey densities, showed different prey handling times (Figure 2). The predator *C. coeruleus* exhibited relatively stable handling times across

all prey-density treatments, requiring less than 1 minute to handle its prey. The predator *Coccinella* sp. required less than 3 minutes to handle its prey at densities of 15, 20, and 25 prey, whereas at densities of 5 and 10 prey it required a longer time, around 4 and 5 minutes, respectively. The Syrphidae predator showed a fluctuating pattern in prey handling time from low to high prey densities. Syrphidae required less than 2 minutes at prey densities of 15 and 25, less than 4 minutes at densities of 5 and 20, and the longest time approximately 7 minutes at a density of 10 prey. In terms of ranking, the fastest to the slowest predators in handling prey were *C. coeruleus*, *Coccinella* sp., and Syrphidae.

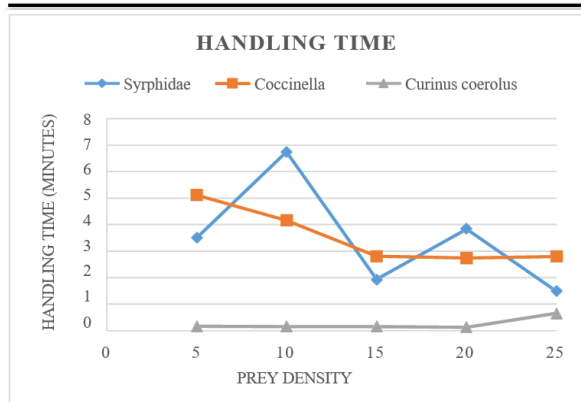


Figure 2. The effect of prey density on the handling time of several predators (Syrphidae, *Coccinella* sp., and *C. coeruleus*)

Average Number of Remaining Prey

The study results presented above indicate the mean number of remaining prey for the Syrphidae predator at each level of prey density and observation interval. At prey densities of 5, 10, and 15 individuals, the average remaining prey was only 1–2 individuals from 1 hour to 24 hours of observation. At the density of 15 prey, after 24 hours of observation, all prey had been consumed by the Syrphidae predator. At a density of 20 prey, the average remaining prey was 7 individuals from 1 hour to 24 hours of observation. Furthermore, at a density of 25 prey, the remaining prey decreased after 24 hours of observation.

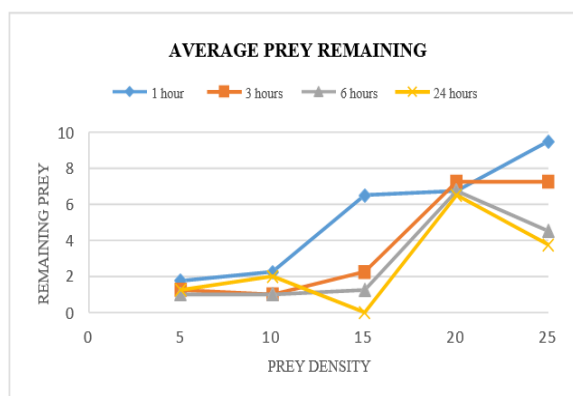


Figure 3. Average remaining prey of Syrphidae predators at different prey densities and observation times

The results presented above demonstrate the average number of remaining prey for *Coccinella* sp. at each level of prey density and observation period. At a density of 5 prey, all prey were consumed by the predator after 1 hour

of observation. At a density of 10 prey, only 1 prey remained after 1 and 3 hours of observation, and all prey were consumed after 6 hours. At a density of 15 prey, the average remaining prey was 5 individuals from 1 to 6 hours of observation, and 3 prey remained at the final observation. At prey densities of 20 and 25, a gradual decrease in the number of remaining prey was observed from the initial to the final observation period.

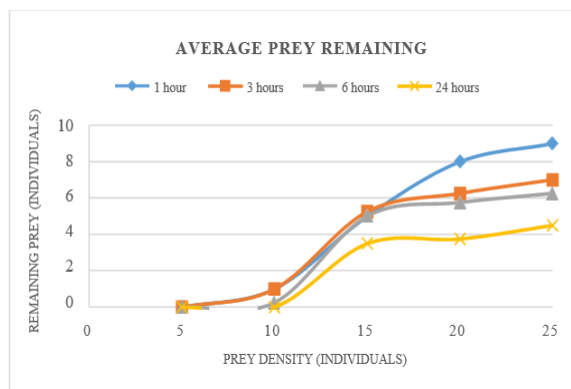


Figure 4. Average remaining prey of *Coccinella* sp. predators at different prey densities and observation times

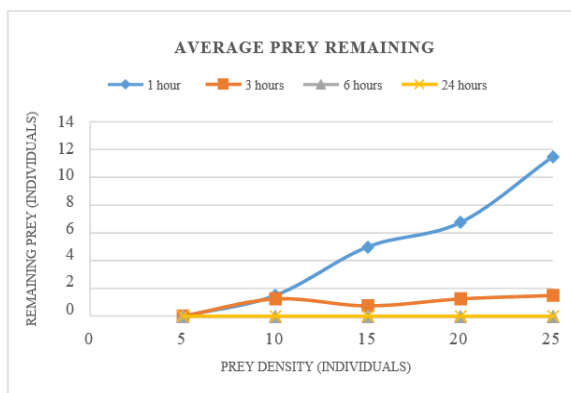


Figure 5. Average remaining prey of *C. coeruleus* predators at different prey densities and observation times

The results presented above demonstrate the average number of remaining prey for *C. coeruleus* at each level of prey density and observation interval. After 1 hour of observation, only at the prey density of 5 individuals were all prey completely consumed by *C. coeruleus*. After 3 hours of observation, the average number of remaining prey was 5 individuals across all prey densities. All prey had been consumed after 6 hours of observation.

Discussion

The effectiveness of a predator in its role as a pest regulator can be measured directly from its predation capacity (its ability to capture and kill prey) (Dunn & Hovel, 2020). Based on this predation capacity, the predator's ability to regulate the balance of its prey population can be assessed. One characteristic of an effective predator is a high searching and hunting ability. The more rapidly a predator locates and captures its prey, the more effective it is as an agent for pest control. (Gonthier et al., 2023). This was evident in the searching time of the predators *C. coeruleus* and *Coccinella* sp. for their first prey. A decrease in the time needed to locate prey occurred as prey density increased (Figure 1A).

Predators are able to locate their prey more rapidly at higher prey densities because the effective search area becomes increasingly restricted. The predator does not need to travel far to locate its prey since prey are abundant. In addition, some predators possess rapid movement abilities, more effective prey-capture mechanisms compared with the prey's defensive strategies, and greater strength than their prey. These factors generally enable predators to capture their prey more easily. The results of these observations are consistent with previous studies indicating that the time required by predators to locate their prey becomes shorter at higher prey densities because the encounter rate between predator and prey increases, thereby improving predation efficiency (Reeves et al., 2024). Nelly et al. (2015) similarly stated that an increase in the density of *Aphis brassicae* reduced the time needed by the predator *M. sexmaculatus* to locate its first prey.

All predators, once introduced into the Petri dish containing prey, appeared very active, moving and exploring to search for their first prey. This was because all predators had been starved for 24 hours beforehand. In particular, *C. coeruleus* appeared very aggressive and showed faster mobility compared with the other predators. During the search for the first prey, *C. coeruleus*, Syrphidae, and *S. annulicornis* were proven to locate their prey more quickly than *Coccinella* sp., requiring less than 5 minutes. After consuming the first prey, the predators then began searching for the second prey. Once a predator found its first prey, the search for

subsequent prey was focused around the area where the first prey was located. This occurred because the prey of these predators *H. cubana* and *R. maidis* often aggregate, making them easier to find.

Similarly, in the search for the second prey, *C. coeruleus* and Syrphidae, also faster in locating their prey than *Coccinella* sp., requiring less than 20 minutes. Compared with the first prey item, a longer time was required by all predators to locate the second prey. This was likely because the predators were already partly satiated after consuming their first prey.

In general, *Coccinella* sp. predators also possess fast prey-searching abilities similar to *C. coeruleus*. For example, the search time of *Coccinella transversalis* for its first prey was only about 1.6 minutes, while for the second prey it required around 1 minute (Rakshith et al., 2021). However, the prey-searching ability of *Coccinella* sp. appeared to be relatively slow. This was because two *Coccinella* sp. predators used during the practicum had entered the pre-pupal stage, causing them to remain mostly inactive and not search for prey. This observation was confirmed after 24 hours when the *Coccinella* sp. larvae that had been in the pre-pupal stage had formed pupae the following day (Figure 6).

A similar condition occurred in one Syrphidae predator used at the prey density of 10 individuals. This Syrphidae predator had also entered the pre-pupal stage, resulting in a much longer search time for its first prey compared with other predators of the same type (Figure 1A).



Figure 6. Predators that had formed pupae at 24 hours after observation; a. Coccinellidae, b. Syrphidae.

Effective predators in pest control possess the ability to handle prey more quickly (short handling time), which increases feeding rate and improves predator efficiency in regulating prey populations (Coblentz & DeLong, 2021; Islam et

al., 2022; Hossie & Murray, 2023). In terms of ranking from the fastest to the slowest prey-handling predators, the order was *C. coeruleus*, *Coccinella* sp., Syrphidae, and *S. annulicornis*. *C. coeruleus* consumes its prey by chewing, as it has chewing-type mouthparts. In contrast, the larvae of *Coccinella* sp. and Syrphidae have piercing–sucking mouthparts, and therefore feed by extracting the body fluids of their prey. The observations in this study show that predators with chewing mouthparts handle their prey more quickly than predators with piercing–sucking mouthparts.

Another factor that may influence prey handling time is the age or developmental stage of the predator. According to Qin et al. (2019), the handling time of the predator *Cryptolaemus montrouzieri* decreases from younger to older stages. This is due to higher prey consumption in the younger stages. However, the observations in this study showed the opposite pattern. The older stage, namely the adult of *C. coeruleus*, handled its prey more quickly compared with the other predators (*Coccinella* sp. and Syrphidae), which were still in younger developmental stages, specifically the larval phase.

Each predator tested had different levels of predation ability or capacity to consume prey. Not all predators were able to finish all of their prey within 24 hours, resulting in some remaining prey still alive in the Petri dish. The Syrphidae predator was able to consume all of its prey only at the density of 15 individuals, *Coccinella* sp. only at densities of 5 and 10 individuals, whereas *S. annulicornis* only at the density of 5 individuals. In contrast, the predator *C. coeruleus* was able to consume all of its prey within 6 hours at all prey-density treatments.

These findings indicate that *C. coeruleus* has a higher predation capacity than the other three predators, making it more effective for pest control. Predators with high predation ability have a greater potential to be developed as biological control agents.

Prey density directly affects the number of prey that can be consumed by a predator, a phenomenon known as the functional response. Based on the observations, all tested predators exhibited an increase in prey consumption as prey density increased. For example, in the predator *Coccinella* sp., when provided with 5 individuals of *R. maidis*, all prey were consumed.

When the number of prey was increased to 10 individuals, the predator was also able to consume all of them. This pattern continued until the predator reached a saturation point, a condition in which it no longer increased the number of prey consumed due to satiation. These findings are in agreement with those of Sierra-Monroy et al. (2025), who reported that the predatory capacity of *Coccinella transversalis* on *Thrips parvispinus* increased as prey density rose. This indicates that prey availability is an important factor determining the activity level and predation effectiveness of a predator. The greater the availability of prey, the higher the predator's potential to consume them. Previous studies have shown that providing prey in excess can stimulate predator activity more strongly than when prey are available in limited quantities, because higher prey availability increases encounter rates and predation efficiency (Rivas et al., 2024).

The findings of this study demonstrated that prey density significantly influenced predator searching time and predation efficiency. As prey density increased, the time required by predators to locate their prey decreased. This pattern is consistent with predator–prey interaction theory, which posits that predators can locate prey more rapidly at higher levels of prey availability due to an increased probability of encounter between predator and prey (Holling, 1959). In ecological research, the time allocated to prey searching constitutes a critical component of predator efficiency and strongly influences the functional response of predators.

Functional response theory posits that a predator's predation rate varies as a function of prey density. One of the most commonly applied models describing this relationship is the Holling Type II functional response, which indicates that predation rate increases with prey density but eventually reaches a plateau due to constraints imposed by handling time. Handling time is defined as the period required by predators to capture, subdue, and consume prey before initiating the search for subsequent prey. As prey density increases, predators devote more time to handling and less time to searching, thereby resulting in a maximum consumption rate. (Holling, 1959; Begon et al., 2006).

The findings of this study indicate that *Curinus coeruleus* showed the fastest searching

time compared with Syrphidae and *Coccinella* sp. predators. This result suggests that *C. coeruleus* has higher mobility and stronger predatory behavior, allowing it to locate prey more efficiently. Previous studies have indicated that *C. coeruleus* is an effective predator of the leucaena psyllid (*H. cubana*) and has been widely introduced in several regions as a biological control agent to suppress psyllid population (Follett & Roderick, 2009).

The variation in handling time among the predators observed in this study may be attributed to differences in mouthpart morphology and feeding behavior. Predators with chewing-type mouthparts, such as coccinellid beetles, generally handle prey more quickly because they directly consume prey tissues. In contrast, predators with piercing-sucking mouthparts, such as Syrphidae larvae, require additional time to extract body fluids from their prey. Consequently, handling time becomes longer in predators that rely on fluid feeding compared with those that consume prey by chewing.

Handling time is one of the principal factors determining predator efficiency in biological control programs. According to ecological theory, predators with shorter handling times can consume more prey within a given period, thereby providing more effective pest suppression. However, the predation rate does not increase indefinitely with prey density, as predators eventually reach a saturation point at which the maximum consumption rate is constrained by the time required to process prey. (Begon et al., 2006).

In addition, predator developmental stage may influence predation efficiency. In this study, some individuals of *Coccinella* sp. and Syrphidae entered the pre-pupal stage during observation, which resulted in reduced mobility and lower feeding activity. This condition likely contributed to the longer searching time observed for these predators. Developmental stage has been reported as an important factor influencing feeding behavior and predation capacity in many predatory insects, as metabolic requirements and feeding activity vary across developmental stages (Omkar & Pervez, 2004; Mirande et al., 2015).

The results also indicate that *C. coeruleus* had the highest predation capacity among the

predators tested. This predator was able to consume all prey at all prey-density treatments within six hours of observation. This finding confirms the potential of *C. coeruleus* as an effective biological control agent. Previous studies have also demonstrated that this predator can feed on several species of plant-sucking insects and has strong predatory ability against psyllids and aphids (Yasin, 2006).

Prey density exerted a direct effect on the number of prey consumed by predators. As prey density increased, consumption also rose until the predator reached a satiation threshold. This pattern is frequently observed in predator-prey systems and represents the functional response of predators. At low prey densities, predators devote a greater proportion of time to searching for prey. However, when prey density is high, searching time decreases and predators allocate more time to handling prey (Barraquand & Gimenez, 2021).

These findings suggest that prey availability is an important factor determining predator effectiveness in biological control systems. A sufficient prey population can stimulate predator activity and enhance predation efficiency. Conversely, when prey density is very low, predators may spend excessive time searching for prey, resulting in reduced predation rates.

Overall, the results of this study provide valuable information regarding predator behavior and predation capacity under different prey-density conditions. A thorough understanding of these ecological characteristics is essential for assessing the effectiveness of predators as biological control agents and for enhancing integrated pest management strategies in agricultural ecosystems.

Conclusion

An increase in prey availability was associated with a reduction in the time required for predators to search for and locate their prey, with *C. coeruleus* recorded as the most rapid predator in this searching process. Predators with chewing-type mouthparts, such as *C. coeruleus*, also demonstrated faster handling of prey compared to predators with piercing-sucking mouthparts, such as *Coccinella* sp. and Syrphidae larvae. In addition, *C. coeruleus*,

exhibited a higher predation ability than the other two predators, making it potentially more effective as a biological control agent. Overall, all tested predators showed an increase in prey consumption as prey density increased, indicating that prey availability is a key factor influencing the effectiveness of predatory activity.

Reference

- Bale, J. S., van Lenteren, J. C., & Bigler, F. (2008). Biological control and sustainable food production. *Trends in Ecology & Evolution*, 23(9), 520–527. <https://doi.org/10.1016/j.tree.2008.05.001>
- Barraquand, F., & Gimenez, O. (2021). Predators' functional response: Biological interpretation of the handling time. *Frontiers in Ecology and Evolution*. <https://doi.org/10.3389/fevo.2021.740848>
- Begon, M., Townsend, C. R., & Harper, J. L. (2006). *Ecology: From individuals to ecosystems*. Blackwell Publishing. <https://doi.org/10.1002/9781444313765>
- Coblentz, K. E., & DeLong, J. P. (2021). Estimating predator functional responses using the times between prey captures. *Ecology*, 102(4), e03307. <https://doi.org/10.1002/ecy.3307>
- Dunn, R. P., & Hovel, K. A. (2020). Predator type influences the frequency of functional responses to prey in marine habitats. *Biology Letters*. <https://doi.org/10.1098/rsbl.2019.0758>
- Follett, P. A., & Roderick, G. K. (2009). Genetic estimates of dispersal ability in the leucaena psyllid predator *Curinus coeruleus*. *Bulletin of Entomological Research*, 99(3), 287–294. <https://doi.org/10.1017/S0007485300034933>
- Gonthier, J., Zhang, Y. B., Zhang, G. F., Romeis, J., & Collatz, J. (2023). Odor learning improves efficacy of egg parasitoids as biocontrol agents against *Tuta absoluta*. *Journal of Pest Science*. <https://doi.org/10.1007/s10340-022-01484-6>
- Gurr, G. M., Wratten, S. D., Snyder, W. E., & Read, D. M. Y. (2017). Biodiversity and insect pests: Key issues for sustainable management. *Biological Control*, 104, 1–3. <https://doi.org/10.1016/j.biocontrol.2016.09.002>
- Heimpel, G. E., & Mills, N. J. (2017). *Biological control: Ecology and applications*. Cambridge University Press. <https://doi.org/10.1017/9781139029117>
- Hodek, I., & Honěk, A. (2009). Scale insects, mealybugs, whiteflies and psyllids (Hemiptera: Sternorrhyncha) as prey of ladybirds. *Biological Control*, 51(2), 232–243. <https://doi.org/10.1016/j.biocontrol.2009.05.018>
- Holling, C. S. (1959). Some characteristics of simple types of predation and parasitism. *The Canadian Entomologist*, 91(7), 385–398. <https://doi.org/10.4039/Ent91385-7>
- Hossie, T. J., & Murray, D. L. (2023). New perspectives and emerging directions in predator–prey functional response research. *Frontiers in Ecology and Evolution*. <https://doi.org/10.3389/fevo.2023.1238953>
- Islam, Y., Shah, F. M., Güncan, A., DeLong, J. P., & Zhou, X. (2022). Functional response of *Harmonia axyridis* to the larvae of *Spodoptera litura*: The combined effect of temperatures and prey instars. *Frontiers in Plant Science*. <https://doi.org/10.3389/fpls.2022.849574>
- Jachowicz, N., Jacobsen, S. K., & Sigsgaard, L. (2025). Molecular gut content analysis reveals predator feeding preferences and potential for biological control of aphids in sugar beet fields. *BioControl*, 70, 627–638. <https://doi.org/10.1007/s10526-025-10334-0>
- Mirande, L., Desneux, N., Haramboure, M., & Schneider, M. I. (2015). Intraguild predation between an exotic and a native coccinellid in Argentina: The role of developmental stage. *Biological Control*, 90, 31–37. <https://doi.org/10.1016/j.biocontrol.2015.05.006>

- Nelly, N., Trizelia, T., & Syuhadah, Q. (2015). Functional response of *Menochilus sexmaculatus* to *Aphis gossypii*. *Jurnal Entomologi Indonesia*, 9(1), 23–31. <https://doi.org/10.5994/jei.9.1.23>
- Omkar, & Pervez, A. (2004). Functional and numerical responses of a generalist predatory ladybird, *Propylea dissecta*. *Journal of Applied Entomology*, 128(2), 140–146. <https://doi.org/10.1111/j.1439-0418.2004.00821.x>
- Qin, Z., Wu, J., Qiu, B., Ali, S., & Cuthbertson, A. G. S. (2019). The impact of *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) on control of *Dysmicoccus neobrevipes* Beardsley (Hemiptera: Pseudococcidae). *Insects*, 10(5), 131. <https://doi.org/10.3390/insects10050131>
- Radyanto, I., Rahayuningtyas, S., & Widhianingtyas, E. (2015). Predatory ability of *Menochilus sexmaculatus* F. (Coleoptera: Coccinellidae) on *Rhopalosiphum maidis* Fitch (Homoptera: Aphididae). *Jurnal Entomologi Indonesia*. <https://doi.org/10.5994/jei.8.1.1>
- Rakshith, H. S., Suroshe, S. S., Chander, S., Rao, C. N., & Deshmukh, A. J. (2021). Bionomics of transverse ladybird beetle *Coccinella transversalis* Fabricius on cowpea aphid *Aphis craccivora*. *Indian Journal of Agricultural Sciences*, 91(9), 1348–1352. <https://doi.org/10.56093/ijas.v91i9.116091>
- Reeves, L. A., Garratt, M. P. D., Fountain, M. T., & Senapathi, D. (2024). A whole ecosystem approach to pear psyllid (*Cacopsylla pyri*) management in a changing climate. *Journal of Pest Science*, 97(3), 1203–1226. <https://doi.org/10.1007/s10340-024-01772-3>
- Rivas, M. J., Cabello, T., Fernández-Maldonado, F. J., & Vila, E. (2024). A predator–prey population dynamics simulation for biological control of *Frankliniella occidentalis* by *Orius laevigatus*. *Biological Control*, 188, 105409. <https://doi.org/10.1016/j.biocontrol.2023.105409>
- Sierra-Monroy, J. A., Deere, J. A., Muñoz Cárdenas, K. A., Montserrat, M., & Janssen, A. (2025). A predatory mite as potential biological control agent of the invasive *Thrips parvispinus*. *BioControl*, 70, 759–770. <https://doi.org/10.1007/s10526-025-10343-z>
- Silva, P. G., Hagen, K. S., & Gutierrez, A. P. (1992). Functional response of *Curinus coeruleus* (Coleoptera: Coccinellidae) to *Heteropsylla cubana* (Homoptera: Psyllidae) on artificial and natural substrates. *Entomophaga*. <https://doi.org/10.1007/BF02373847>
- Solomon, M. E. (1975). Review of biological control by natural enemies. *Experimental Agriculture*, 11(2), 159–160. <https://doi.org/10.1017/S0014479700006621>
- van Lenteren, J. C. (2012). The state of commercial augmentative biological control: Plenty of natural enemies, but a frustrating lack of uptake. *BioControl*, 57(1), 1–20. <https://doi.org/10.1007/s10526-011-9395-1>
- Williams, A. C., & Flaxman, S. M. (2012). Can predators assess the quality of their prey's resource? *Animal Behaviour*, 83(4), 883–890. <https://doi.org/10.1016/j.anbehav.2012.01.008>
- Yasin, N. (2006). Development and predation ability of *Curinus coeruleus*. *Jurnal Hama dan Penyakit Tumbuhan Tropika*, 6(2), 79–86. <https://doi.org/10.23960/j.hptt.2679-86>