



Predatory Efficiency of *Anisops sardea* and *Sigara lateralis* Against *Culex quinquefasciatus* Larvae in Basra, Iraq

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ABSTRACT

Two hemipteran species (order Hemiptera) were sampled from five locations in Basra (Abu Al-Khasib, University of Basra, Al-Sharsh, Al-Qurna, and Al-Sadiq district) during January 2024 to December 2024. The first predator is *Anisops sardea* (Herrich-Shaeffer, 1849) of the Notonectidae family, and the second predator is *Sigara lateralis* (Leach, 1818) of the Corixidae family. Their predatory efficiency against *Culex quinquefasciatus* mosquito larvae was studied in Basra Governorate. The study proved that backswimmer *Anisops sardea* are more efficient predators, with a daily predation rate of 17.33 larva/day, compared to the water boatmen *Sigara lateralis*, which had a daily predation rate of 7.66 larvae/ day. The study showed that females are more predatory than males in both predatory species. The effect of high water levels on predation efficiency was studied, and a manifest effect was found, as a decrease in the daily predation rate was observed for both predators: 12 larvae/ day for the backswimmers *A. sardea* and 5 larvae/ day for the water boatmen *S. lateralis*. The results of the synergistic study between the first and second predators showed that the daily predation rate reached 25 larvae/day

INTRODUCTION

Mosquitoes are among the most widespread insects, indeed living organisms, in the world due to the deadly pathogens they transmit. Mosquito-borne diseases are among the most prominent threats to public health worldwide, causing hundreds of millions of people to contract serious illnesses such as malaria, dengue fever, Zika virus, and yellow fever annually. Global data show that malaria alone affects more than 200 million people annually, resulting in the death of more than 600,000 people, the majority of whom are children in parts of Africa (Eba *et al.*, 2021). In Arab countries and the Nile Basin countries, this issue is gaining further importance due to the presence of aquatic environments conducive to mosquito breeding, in addition to climatic conditions that facilitate the spread of disease vectors (Saleem *et al.*, 2023; Yaseen *et al.*, 2024). Vector control strategies are among the most important means of reducing the burden of

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mosquito-borne diseases on public health. Before the invention of insecticides, these strategies focused on environmental management, particularly eliminating mosquito breeding grounds and improving homes by installing screens to prevent entry through doors and windows. Then insecticides were used as an effective and rapid method of mosquito control, especially after World War II (**Wilson, et al., 2020; Karim et al., 2022**). Given the numerous disadvantages of chemical pesticides, including the killing of non-target organisms in control and the emergence of resistance to pesticides in mosquitoes, as well as concerns about their danger to the environment and public health, the use of manufactured chemical insecticides to control disease vectors is declining. Therefore, interest in alternative control strategies has long existed, and in light of these conditions related to disease vector control, biological control measures have been found to be the optimal alternative (**Liu, 2015; Jacob et al., 2017**).

Reports indicate that biological control methods have emerged as the best alternatives to synthetic pesticides, and show promising results in containing vector numbers below critical levels (**Naik, 2018**). Moreover, in light of the environmental crisis and global changes, environmentally friendly methods should be encouraged (**Roux & Robert, 2019**). Mosquito larvae and their predators coexist in diverse aquatic environments, ranging from small and temporary aquatic environments to large and permanent sites. Many large invertebrate predators from the orders Dragonflies, Beetles, and Hemiptera have been shown to be potential biological control agents against mosquito species (**Aditya & Saha, 2006; Mandal, et al., 2008**). Predatory insects of the orders Hemiptera, Odonata, and Diptera have been reported to be globally widespread and promising for biological control (**Moirangthe, et al. 2018; Aldoghachi, 2022**). Predation of mosquito larvae, with a preference for prey in later stages of development, may contribute to a significant reduction in mosquito population density (**Makhlouf & Khadir 2016; Al-Hassani, 2017; Al-Kanaani, 2018; Crane et al., 2019**). Some predatory species, such as *Anisops* spp., Belostomatidae, *Gerris* spp., Nepidae, and Notonectidae, are effective in mosquito control in various parts of the world (**Dambach, 2020**).

Therefore, in this study we will focus on two types of predators belonging to the order Hemiptera. It is widely distributed in multiple environments globally, such as lakes, ponds, marshes, and estuaries. They live in stagnant and flowing water environments and prefer small ponds and marshes with dense vegetation and no predatory fish. The two predatories are the water boatman *S. lateralis* (**Leach, 1818**) and the family Corixidae. It is distinguished by important features including large eyes located on the sides of the head, piercing-sucking mouthparts, and short, four-segmented antennae. The legs exhibit a clear diversity of functions, with each set of legs modified for specific purposes. The front legs are short but strong, equipped with dense bristles that act as filters to collect food from the water and sediment. These legs move quickly and rhythmically, similar to paddling, hence the name "Water Boatmen." The middle legs are long and thin, used for

gripping and steering while swimming. The hind legs are the most developed; they are long, flat, and covered with long, dense bristles, creating a large surface area that acts as paddles powerful to propel the insect underwater. These designs allow the insect to swim quickly and efficiently in various aquatic environments (Aufy, 2023; Gopal *et al.*, 2023). The back-swimming insects, *A. sardea* (Herrich-Shaeffer, 1849), belong to the family Notonectidae, one of the most distinctive and specialized families of aquatic insects. This family is characterized by a unique set of morphological adaptations that allow them to swim on their backs and hunt efficiently in the water. Members of this family range in length from 5 to 17mm. Their bodies are spindle-shaped and smooth with a slight bulge in the middle, which helps reduce water resistance and increase swimming efficiency. The upper surface of the body is noticeably convex and covered with a dense layer of tiny, water-repellent hairs, which play a crucial role in retaining the shiny, silvery air bubble that surrounds it. While swimming in the water, this air bubble acts as an oxygen reservoir, and also helps with buoyancy and controlling the depth of swimming (Das & Maity, 2023; Al-Atbee *et al.*, 2025).

Therefore, the current study seeks to compare the predatory efficiency of these two types of predators, *S. lateralis* (Leach, 1818) and *A. sardea* (Herrich-Shaeffer, 1849), against the larvae of *C. quinquefasciatus* mosquitoes prevalent in Basra Governorate.

MATERIALS AND METHODS

Collected and Predator Breeding

Samples of predatory insects were collected from various location in Basra Governorate, including five permanent location and more than 122 secondary stations covering most areas of Basra. The insects were collected from temporary and permanent ponds using a manual net measuring 10 x 10cm with 100-micron openings. Three replicates were selected from each station, and the insects were then placed in 500ml plastic bottles. They were then transferred to the laboratory and placed in 10-liter plastic tanks for rearing and acclimatization. The tanks were filled with tap water, which was left to stand for 24 hours before the insects were added. The predators were fed mosquito larvae. The predators were sent to the Natural History Museum at the University of Basra for identification and were identified by Dr. Muslim Ashour.

Collecting and Breeding Mosquitoes

The immature stages of mosquitoes were collected from ponds inside the University of Basra near the Marine Science Center using a square-shaped scoop with dimensions of 10 x 10 x 10cm and a capacity of half a liter, with a wooden handle half a meter long. The scoop was quickly submerged in the water at a 45-degree angle to the water surface, taking care not to fill the scoop to avoid spilling water during the scooping process the collected insects are placed in plastic bottles for transport to the laboratory for laboratory experiments. They are then placed in 10-liter plastic tanks containing filtered water from

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mosquito breeding ponds for rearing purposes. Upon reaching the pupal stage, in order to obtain a pure permanent culture, the newly hatched pupae were transferred using a wide-mouthed dropper to plastic containers placed in a cubic wooden cage with sides measuring (50) cm, lined with tulle fabric. Inside, Petri dishes containing cotton saturated with a (10%) sugar solution were placed to feed the newly hatched adults. To obtain egg boatmen, the method of **Mohsen and Mahdi (1989)** was followed. Samples of the third-generation larval stages were taken for identification purposes at the Natural History Museum/ University of Basra and confirmed to be *C. quinquefasciatus* from the family Culicidae. It should be noted that the insect was reared and cultured under laboratory conditions at a temperature of 28°C, humidity of 55%, and an average light intensity of 12 hours (**Al-Sharrook et al., 1991; Sahi & Khudair, 2015**).

Evaluation of Predatory Efficiency

Predatory efficiency was estimated using the third and fourth larval stages of the mosquito *C. quinquefasciatus* to avoid pupal transformation and because the large size of the larvae in these two stages is preferred by predators. The treatments were carried out with three replicates for each treatment one predator was placed with 25 prey, with three replicates, and a control group with the same prey density was kept under laboratory conditions. The experiment was repeated with increased prey density to 50 and 75 for three consecutive days, and the consumed larvae were counted after 24 hours for each replicate. The experiment was also repeated with increased predators (two and three) and prey densities of 25, 50, and 75.

The Effect of Water Volume on Predatory Efficiency

The effect of water volume on the predatory efficiency of predators was studied by repeating the previous experiment with an increased water volume of two liters. The same experiments were repeated for the predators, but only the water volume was different.

The Effect of Sex on Predation Efficiency

Previous predator experiments were repeated, but for each predator, the predation efficiency of the males was measured and compared to the predation efficiency of the females.

The Search Effectiveness

The search effectiveness of the predators *A. sardea* and *S. lateralis* was estimated using three densities of 25, 50 and 75 prey per treatment, with three replicates placed in 5-liter glass tanks. One predator from each of the two species was placed in each treatment, and a control treatment was left without a predator. The search effectiveness was calculated according to the equation (**Beddington et al., 1975**).

$$E = \frac{Na}{N.P}$$

Where, E = predator's hunting efficiency, Na = number of prey consumed per unit volume and time, N = prey density, p = predator density.

Synergy Between Predators

The synergistic predator experiment was conducted by placing them together in a one-liter container and adding 25 mosquito larvae prey, with three replicates for each treatment. This was compared to each predator individually, at the same prey density, while leaving a control treatment without predators. The synergistic effectiveness was calculated according to the equation:

$$PS = 1 - \frac{P1+P2}{\Sigma P1P2} \times 100$$

Where, PS = Predatory Synergy, P1 = Number of prey consumed by the backswimmer,

P2 = Number of prey consumed by the water boatmen

$\Sigma P1P2$ = Total number of prey consumed by both predators together

Statistical Analysis

The experiments were conducted using a completely randomized design (CRD). Means were compared using the least significant difference (LSD) test at a probability level of ($P < 0.01$) using GenStat software. 2009 for Windows, 8 Edition. UK. Web page: GenStat.co.uk

RESULTS AND DISCUSSION

Figs. (1, 2) show significant differences in the daily predation rate of the predator *A. sardea*. The highest daily predation rate was 17.33 prey/day on the first day at a density of 25, and the predation rate increased to 32.66 prey/day at a density of 50. At a density of 75 prey, the highest predation rate was 40.66 prey/day for the backswimmer predator. Similarly, for the second predator, *S. lateralis*, the highest rate of predatory efficiency reached 8 prey/day on the first day at a density of 25 prey, and the rate of predation increased with increasing prey density, reaching 10 and 12 prey/day at densities of 50 and 75, respectively.

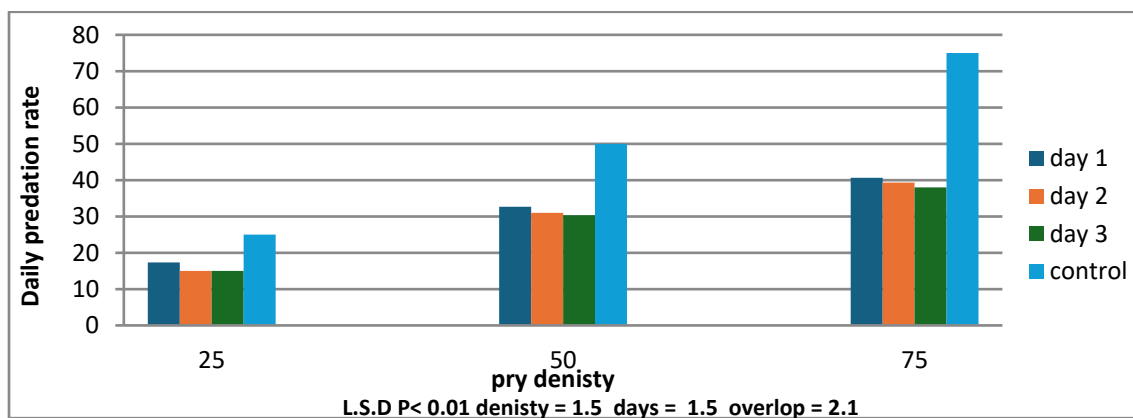


Fig. 1. The Predatory Efficiency Rate of the Predator *A. sardea* Illustrates the Predation Experience of One Predator

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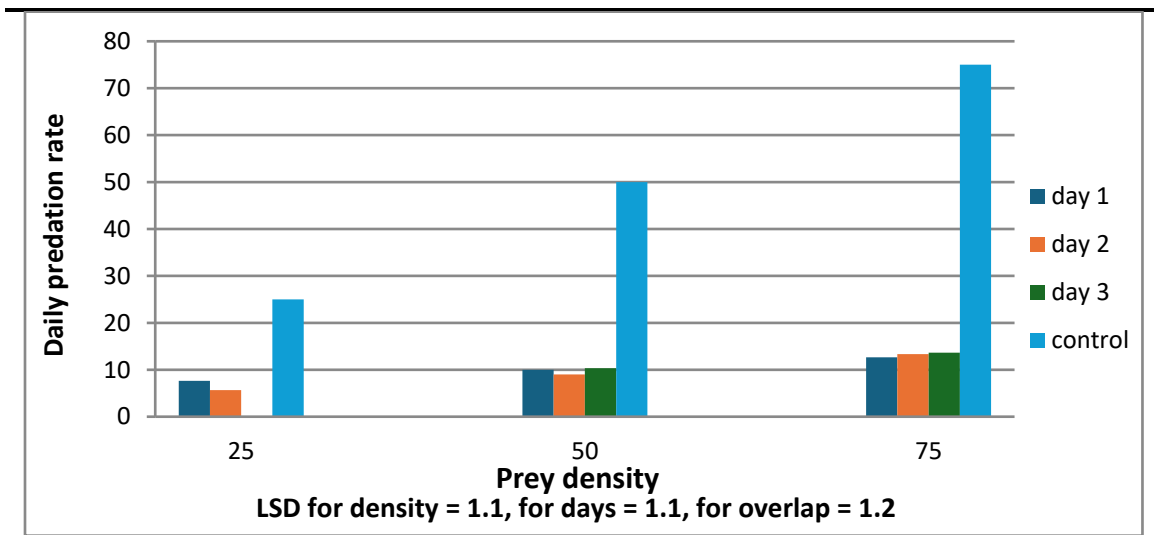


Fig. 2. The Predatory Efficiency Rate of the Predator *S. Lateralis* Illustrates the Predation Experience of a Single Predator

When prey density is increased and there is more than one predator present in laboratory experiments than what is found in the nature, an increase in the daily predation rate was observed for both predators used in the experiments. The number of predators was increased to two and three predators at densities of 25, 50, and 75 prey. The daily predation rate for the first predator *A. sardea* was recorded as 25 prey in both cases of two and three predators at densities of 50 and 75. The highest predation rates on the second day were 41 and 48, respectively, as shown in Figs. (3 and 4). For the second predator *S. lateralis* (water boatman), the daily predation rate also increased with increasing predator density.

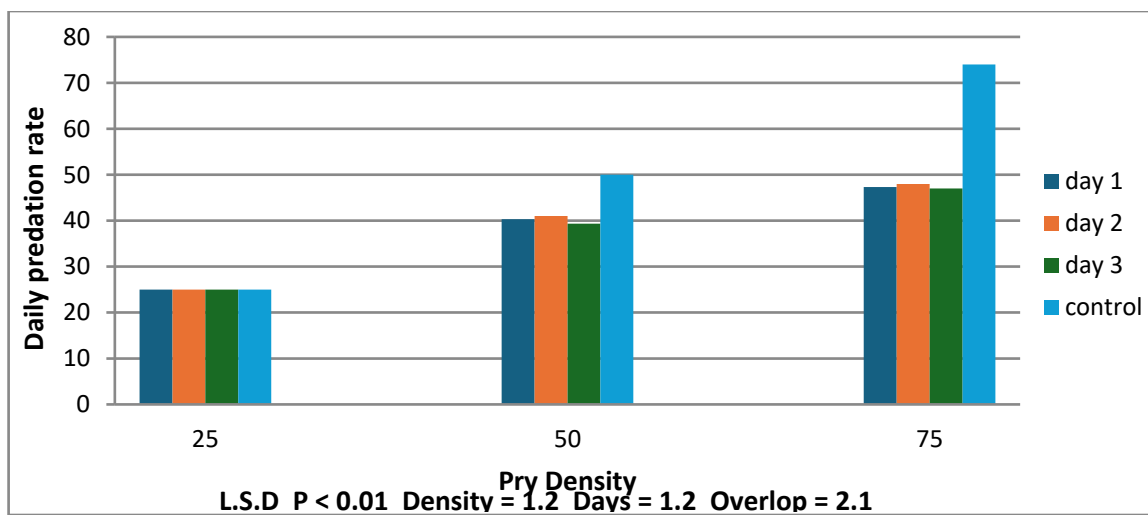


Fig. 3. The Predatory Efficiency Rate of the Predator *A. sardea* Illustrates the Predation Experience of Two Predators

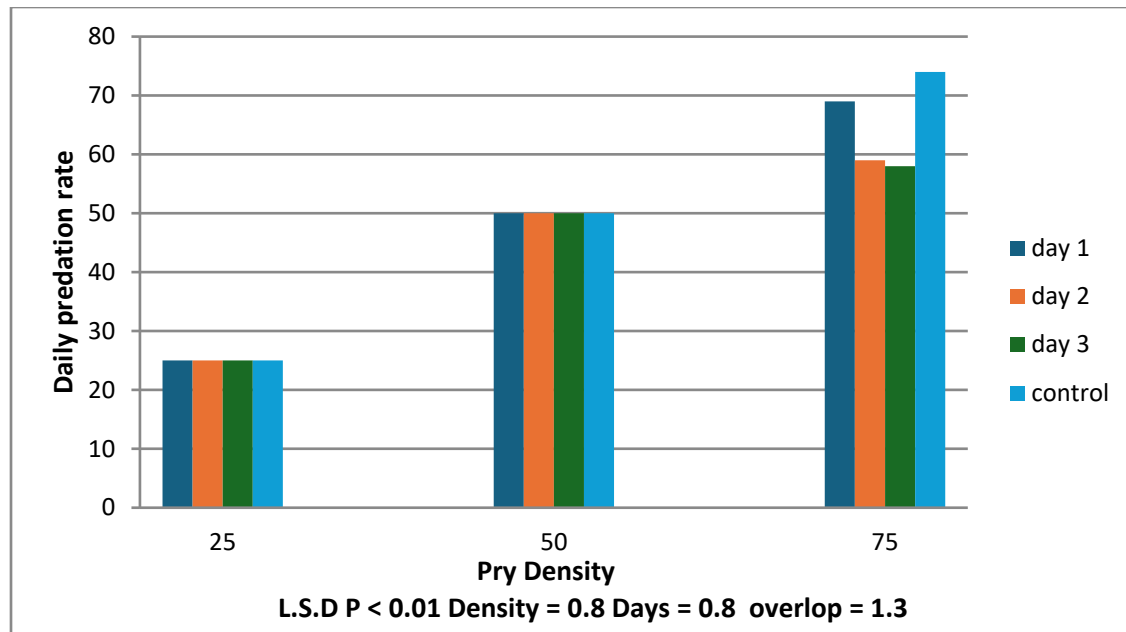


Fig. 4. The Predatory Efficiency Rate of the Predator *A. Sardea* Illustrates the Predation Experience of Three Predators

The highest daily predation rate at a density of 25 was 17.33 on the first day, and at a density of 50, the highest daily predation rate was on the third day, reaching 26.33 and 36 prey/day, respectively, as shown in Figs. (5, 6).

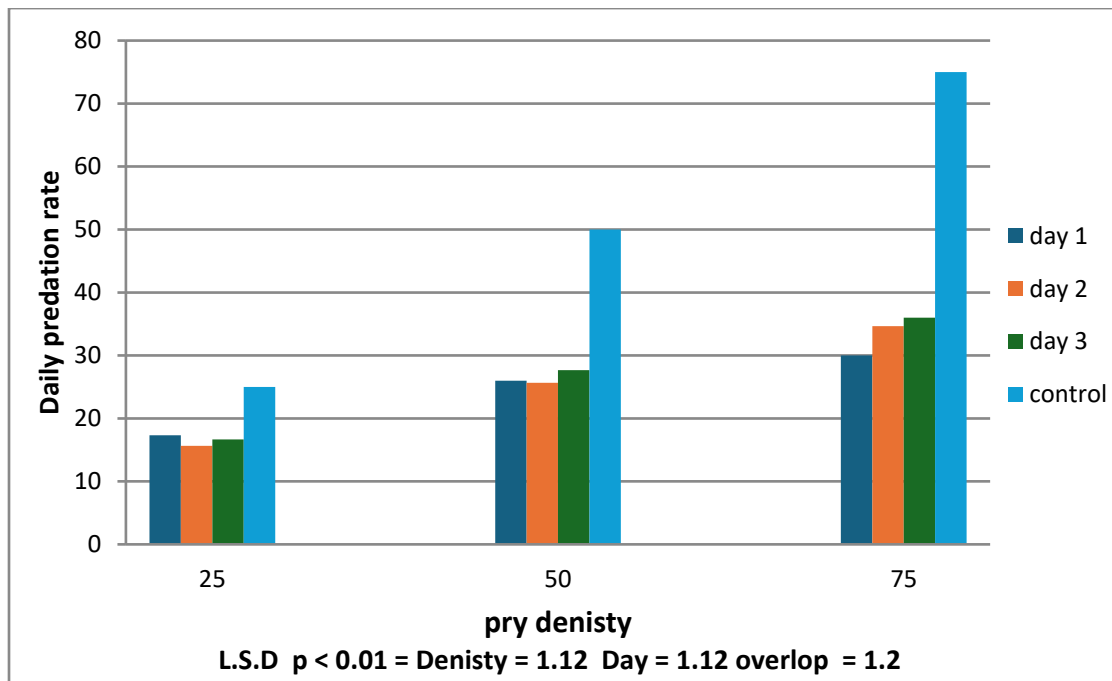


Fig. 5. The Predatory Efficiency Rate of Two Predators of *S. Lateralis* with Different Prey Densities

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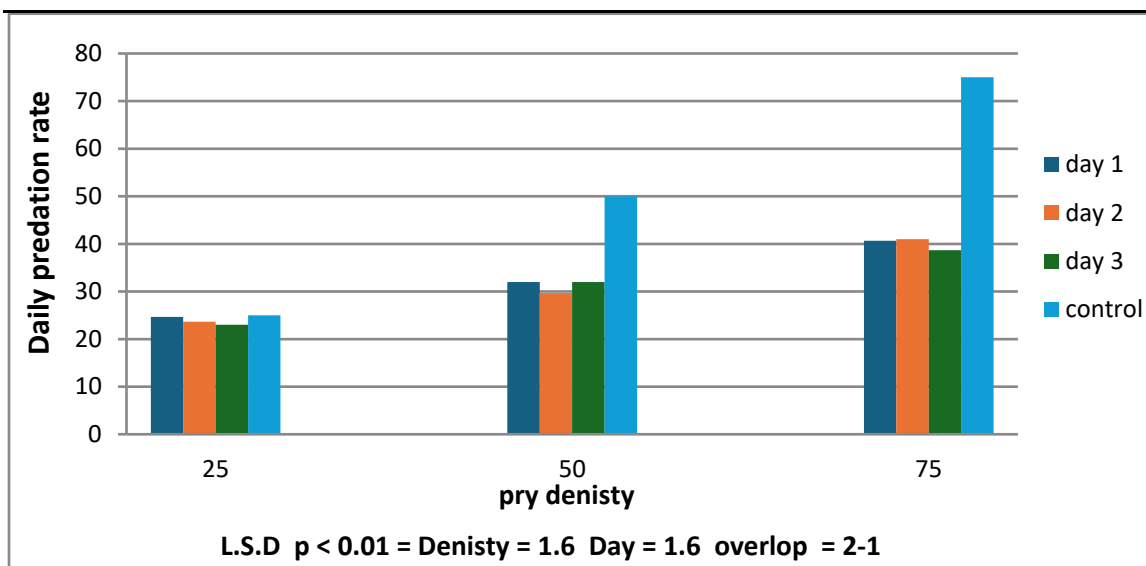


Fig. 6. The Predatory Efficiency Rate of Three Predators *S. Lateralis* with Different Prey Densities

The Effect of Water Volume on Predatory Efficiency

Figs. (7, 8) show the effect of water height on the predatory efficiency of the predators under study, compared with previous experiments shown in Figs. (1, 2). The volume of water used was one liter in the experiment, while when the volume of water was increased to two liters, the predatory efficiency changed, as the highest rate of predation for the backswimmer reached 13 prey/day compared to 17.33 in the one-liter water volume. The highest predation rate for water boatmen was 5 prey/day compared to 8 prey/day at a water volume of 1 liter and a prey density of 25 for both predators. Similarly, at a density of 50 on the first day, the highest predation rate was 22 prey for the backswimmers compared to 32 at a water volume of 1 liter.

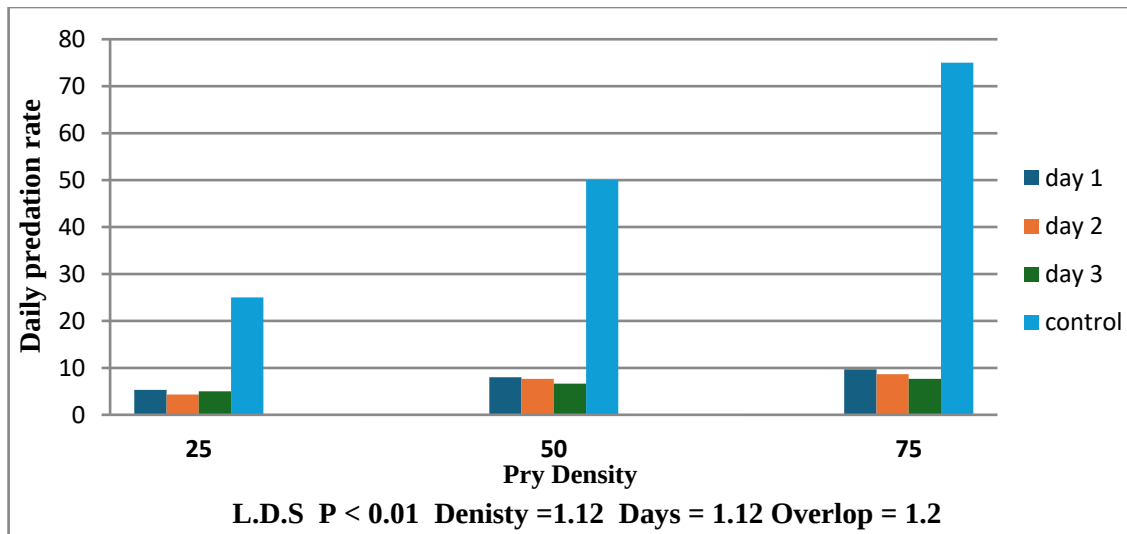


Fig. 7. The Daily Predation Rate of the Predator *S. lateralis* in a 2-Liter Water Volume

While the average predation rate on the second day for water boatmen was 8 prey/day compared to 10 prey at a water volume of one liter and at a density of 75, the predation efficiency also decreased and was affected by the water volume, as the average daily predation rate for the backswimmers was 29.67 prey/day compared to 40 prey at a water volume of one liter, while the average daily predation rate for waterboatmen was 9.66 prey/day compared to 12 prey at a water volume of one liter.

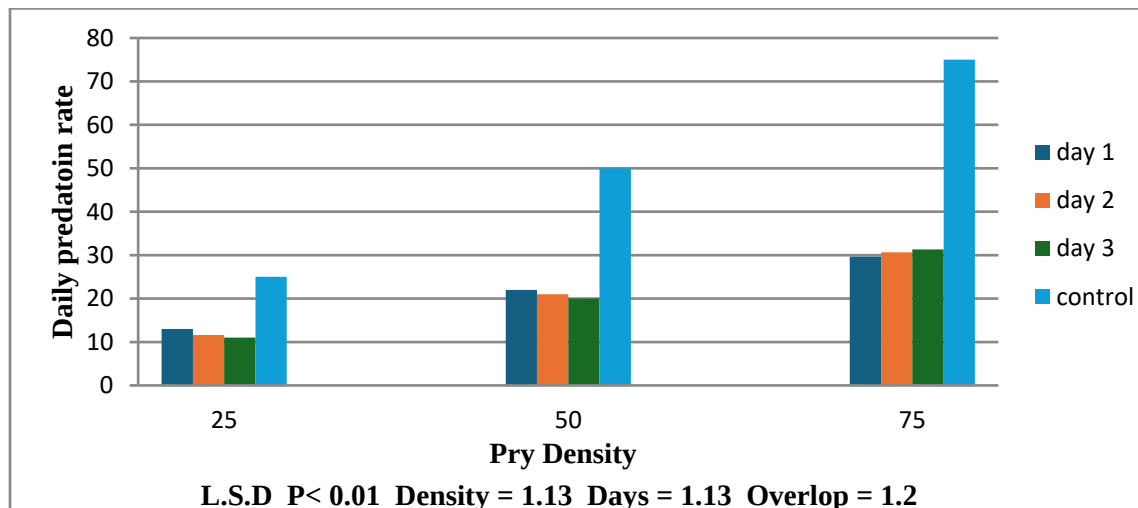


Fig. 8. The Daily Predation Rate of the Predator *A. sardea* in 2-Liter Volume of Water Showing the Predatory Efficiency; Male and Female

Figs. (9, 10) show significant differences between males and females in daily predation rates. The highest predation rate on the first day was 18.66 for females compared to 15 prey/day for males in the backswimmer species, while the daily predation rate for females was 9.66 compared to 7 prey/day for males in the water boatman predator.

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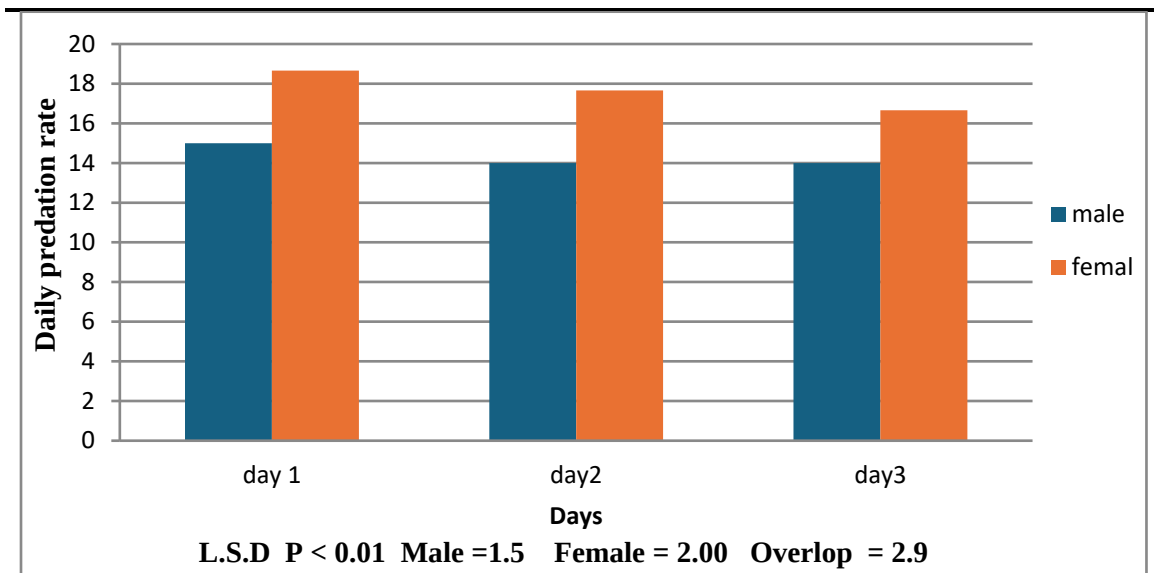


Fig. 9. The Predation Rate Between Males and Females of the Backswimmer Predator

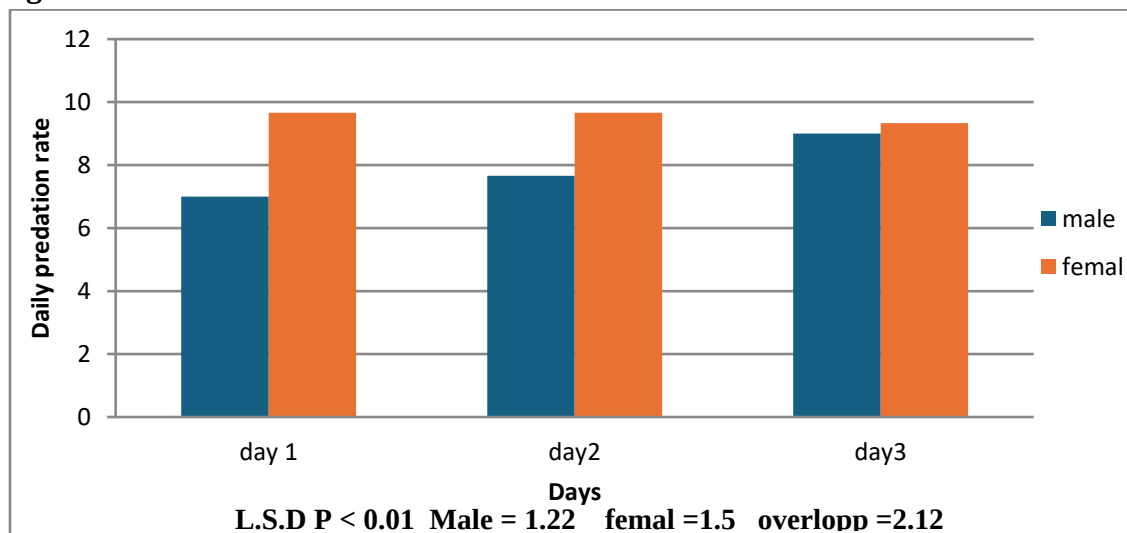


Fig. 10. The Predation Rate Between Males and Females of the Water Boatman Predator

The Effect of Synergy on Predatory Efficiency

From Fig. (11), it is observed that there is a synergistic process between the predators, thus proving that they coexist in the same environment and no predation occurs between them, since the predation rate increased by 5%, which encourages the use of both predators in the biological control of mosquito larvae.

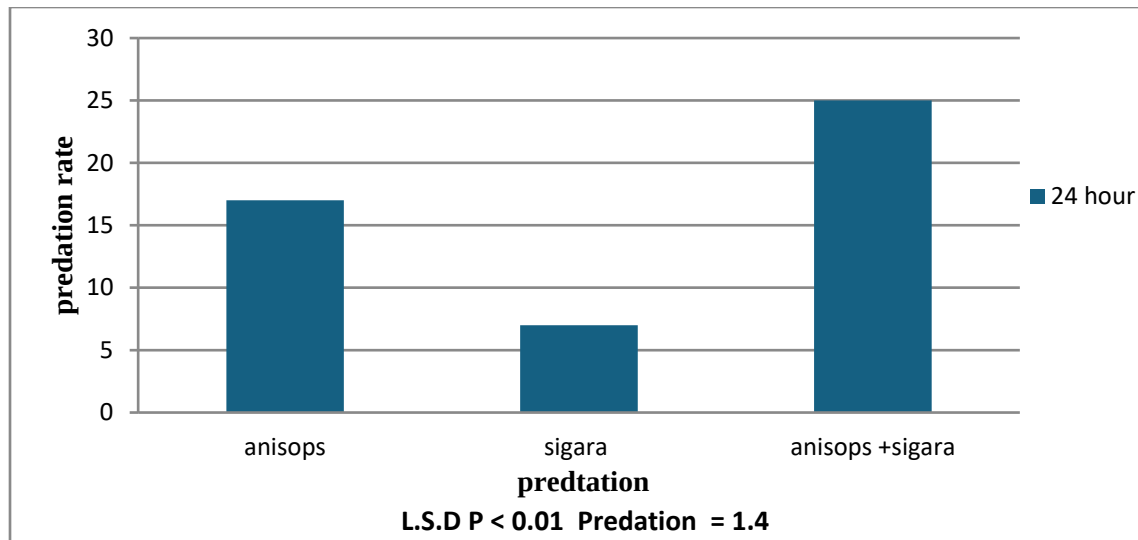


Fig. 11. Effectiveness of the Synergy Between Predators

Predatory efficiency increased with increasing prey density, while hunting efficiency decreased as prey density increased below a constant water volume of 1L. The highest predatory efficiency for the backswimmer was 40 at a density of 75 prey/liter, decreasing to 32.66 prey at a density of 50 prey/liter. The lowest predatory efficiency was 17.33 prey at a density of 25 prey/liter, while the highest predation efficiency for waterboatmen was 12.66 prey at a density of 75 prey/liter; at a density of 50 prey/liter, the predation efficiency decreased to 10 prey, and the lowest was at a density of 25 prey/liter. Therefore, the search efficiency increased when the prey density decreased from 75 to 25 prey. Additionally, the search efficiency reached 0.7 at a density of 25 and decreased to 0.5 at a density of 75 for backswimmers, and the same applies to water boatmen, as shown in Table (1).

Table 1. The Effectiveness of Prey Hunting by Predators

Predator	Density of Prey	Average consumption of a predator	Search effectiveness	Average consumption of a predator
<i>Anisops sardae</i>	75	40 a	0.5	53
	50	32.66 b	0.65	64
	25	17.33 h	0.7	68
<i>Sigara lateralis</i>	75	12.66 c	0.16	16
	50	10 d	0.2	20
	25	7.66 e	0.3	28

Numbers with different letters in the column indicate significant differences at a probability level of 0.01% according to Duncan's test.

DISCUSSION

The results showed that *A. sardea* exhibited higher predatory efficiency than *S. lateralis* at different water densities and volumes, as shown in Figs. (1, 2, 3, 4, 5 and 6). This might be ascribed to being voracious predators of mosquito larvae, preferring them over other prey species. **Al-Rashidi (2017)** demonstrated that *A. sardea* prefers mosquito larvae over other prey when present in the same environment. The backswimmers are more efficient predators because of their extended life, extensive distribution in water bodies and their unique feeding habit. Conversely, *Sigara lateralis*, though able to prey on other organisms, exhibits lower predatory efficacy since it is an omnivorous species that largely feeds on aquatic plants, algae, and miscellaneous organisms. When studying the effect of water volume on the predatory efficiency of predators, a decrease in the predatory efficiency rate was observed for both predators, as shown in the results depicted in Figs. (7, 8). This may be due to the height of the water column, which means the predators need more time to capture their prey. Additionally, *Culex* mosquito larvae remain still near the water's surface to breathe; therefore, the water level affects their predatory rates. This result is consistent with the studies of **Ohba and Ushio (2015)** and **Al-Baghdadi et al. (2024)** which compared the effect of water depth on the predation rates of two types of mosquitoes, *C. tritaeniorhynchus* and *A. albopictus*. An increase in predation efficiency was observed with an increase in prey density, while search effectiveness decreased in high densities, as shown in Table (1). The results of this study is consistent with the findings of **Mukhlif and Khadir (2016)**. In their study, when the two predators worked together, the rate of predation increased by 5%, as documented in Fig. (11), which illustrates the synergy between predators, confirming that the predators together exhibited good predation efficiency compared to each predator alone. The findings show that the two predators co-exist in the same environment. The field sampling of the various study stations revealed that two predators were coexisting in most of the sampled areas. Moreover, as shown in Figs. (9, 10), females showed higher predation activity than males since females need protein for reproduction and larger egg output, which is referred to in the studies of **Aldoghachi et al. (2019)** and **Dahir et al. (2025)**.

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