

Full Length Research Paper

Impact of water-ph values on the consumption capacity of certain aquatic insects preying on different medical snails

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The main aim of this work was to determine the consumption capacity of five aquatic insects (as predators) on four species of medical snails (as preys) tested under four values of pH at a constant and controlling temperature in the laboratory. The predators were represented by adults of two hemipterous species (*Limnogeton fieberi* Mayr, *Sphaerodema urinator* Duf.) and three nymph odonatous species (*Anax imperator* Leach, *Crocothemis erythraea* Brulle and *Ischnura pumilio* Charp.). Moreover, the four water-pH values were 5, 7, 9, and 11 at 30°C. On the other hand, the four prey of the medical snails were *Bulinus truncates* Audouin, *Biomphalaria alexandrina* Ehrenb, *Cleopatra bulimoides* Olivier and *Melanoides tuberculata* Muller. All of individual fauna were collected from the River Nile in Qena. The acidic media were adjusted as a mixture of three acids phosphoric acid acetic acid boric acid. In contrast, the alkaline solution was prepared by sodium hydroxide. The results illustrate that, the maximum predation occurred under 7 pH and 9 pH at 30°C regardless of the laboratory conditions. It appeared that *Bulinus truncates* was highly preferable snail species to these predators. *Biomphalaria alexandrina* which is the intermediate host of *Schistosoma mansoni* Bilharz, may be the lastly preferable snail species to these predators. The belostomatids (*Limnogeton fieberi* and *Sphaerodema urinator*), and the odonats (*Anax imperator*, *Crocothemis erythraea* and *Ischnura pumilio*), could be the highest successful predators on the harmful snails (*Bulinus truncates*, *Melanoides tuberculata*, *Biomphalaria alexandrina* and *Cleopatra bulimoides*). Therefore, its use should be encouraged to be reared in large numbers and then released in the natural places of snails under 7 to 9 range values of water pH.

Key words: *Bulinus truncates*, *Biomphalaria alexandrina*, *Schistosoma mansoni*, The belostomatids (*Limnogeton fieberi* and *Sphaerodema urinator*), and the odonats (*Anax imperator*, *Crocothemis erythraea* and *Ischnura pumilio*), predation Odonata, Hemiptera, snails and pH values.

INTRODUCTION

Predator-prey interactions are important in shaping the community and population structure in freshwater aquatic systems. Moreover, the aquatic entomofaunal predators represent essential agents for water purification against several vectors and microbial hosts. In addition, these predator agents are considered the main food for the

more important economic aquatic vertebrates such as fishes. The main predators are odonatous and hemipterous species which attack different medical snails. Succeeding the predation process perhaps depend on the ambient chemical and physical conditions under which this process take place.

Several authors investigated predation by the hemipterans and odonatans attacking various aquatic harmful faunal taxa for instants under normal or abnormal conditions. Hudson and Berrill (1986) studied the tolerance of

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low pH exposure by the eggs of dragonflies and damselflies of the order Odonata. They worked on eggs of *Ischnura verticalis*, *Lestes congener* and *Libellula Lydia* as predators. Moreover, they suggested that tolerance of low pH, soft water conditions in part account for the widespread distribution of Odonata in potentially acid stressed regions. Kesler and Munns (1989) worked on predation by *Belostoma flumineum* (Hemiptera) to proof an important cause of mortality in freshwater snails. The effects of low pH on predation rate and caloric content of nymphs of damselfly nymphs *Enallagma civile* (Odonata: Coenagrionidae) was studied by Gorham and Vodopich (1992). They suggested that predation rate was significantly lower in artificially reconstituted soft water (RSW) than in pond water in treatments of equivalent H^+ concentrations. Appleton et al. (2004), showed that predators of freshwater pulmonate snails in Africa were specially *Appasus grassei* (Heteroptera)

The functional responses of *Laccotrephes griseus* (Hemiptera: nepidae) against culex quinquefasciatus (Diptera: culicidae) were studied in laboratory bioassay by Berg (1973). Saha et al. (2004) examined the response of hemipteran predation to light and other habitat factors for getting the best successful result of killing the culicid individuals. In addition, Culler (2008) investigated macroinvertebrate predators including some belostomatids and their role in shaping freshwater communities in constructed Wetlands.

In Egypt, Osman (2001) investigated predation via one belostomatid species (*Sphaerodema urinator*) on two medical snails (*Bulinus truncatus* and *Biomphalaria alexandrina*) under the room conditions. The results revealed that control by *Sphaerodema urinator* on the *B. truncatus* was successful, while it failed to controlled *B. alexandrina*. Studies of Shaalan and Canyon (2009) covers the predation of different insect species on mosquito larvae, predator-prey –habitat relationships in addition to predatorial capacity.

The main purpose of the present work was to study the effect of different value of water pH on consumption capacity by Egyptian fresh water predatory insects for medical snails at a controllable degree of temperature in the laboratory.

MATERIALS AND METHODS

The study of aquatic insects associated with harmful snails in fresh water habitats were carried out through irregular samples collected from Qena city. The experiments were conducted in the laboratory to examine the consumption capacity of the previous predators (insects) towards the different snails species which exist under different pH values at 30°C as natural temperature.

Five individuals of each predator (the same species) were isolated in plastic container, filled with field water. Five containers were used, and covered by a perforated membranous plastic to prevent escape of the insects, (Abou El- Ela et al. 2003); the water was changed (every alternate day) to avoid the water fouling. The results were observed daily at the same time for ten days. So, every aquaria contained five individuals of predators (of the same species) and 50 individuals of preys (of the same species) merged

in liter of distilled water. Each aquaria were repeated five times. The experiments were prepared and placed in an incubator adjusted at 30°C for ten days. The numbers of consumed or killed preys were recorded every 24 h. An equivalent number of snails was replenished to the experimental sets provided with electric wires. Float foam rubber pieces was put in water for the insect to crawl and settle, instead of aquatic grasses and plants used by other investigators to avoid fermentation of plants and keeping water quality. The daily consumed snails of each predator species were replaced and counted.

In the beginning of the experiments, the predators and preys must be weighed to determine the weight of each insect or snail. The predators were starved for two days. Rearing of aquatic snails was made by the same technique described by Azzam and Tawfik (1997).

Preparing and adjusting the pH values

Ambient media of the acidic solutions

Acidic solution was prepared as a mixture of the following acids: phosphoric acid (H_3PO_4), 1 ml /L of distilled water; acetic acid (CH_3COOH), 1 ml/ L of distilled water; boric acid (H_3BO_3), 7.42 g/L of distilled water.

Then, the three acidic solutions were mixed together to be 3 L of acidic buffer solution; to control the solution of the experiment (to be acidic).

Alkaline solutions

Alkalinity solution was prepared by taking the atomic weight of Sodium Hydroxide (NaOH); Na (22.9898), O (15.9994), and H (1.0079). So, the total atomic weight of NaOH was 39.9971. This weight was dissolved in 1 L of distilled water to obtain the alkaline solution to control the solution of the experiment (to be basic).

20 treatments were done in this experiment under four pH values (5, 7, 9 and 11 pH), to all predators. In addition, 20 treatments under laboratory conditions were repeated as the control of this experiment.

Identifications of different collections

Identifications were performed in for the different collections in the Zoology Department, Faculty of Science, South Valley University (particularly Dr Ibraheem E.E.,) in addition to some key textbooks and catalogs such as how to know the aquatic insects, a key to the Italian Odonata, the semi aquatic bugs, Bestimmungsschlüssel fuer die Saprobier-DIN-Arten.

Therefore, five aquatic predators were identified and available with enough number of individuals as follows: two adult hemipterous species which are *Limnogeton fieberi* Mayr, *Sphaerodema urinator* Duf. (Belostomatidae); three nymphal odonatus species, *Anax imperator* Leach (Aeshnidae), *Crocothemis erythraea* Brulle (Libellulidae) and *Ischnura pumilio* Charp.(Coenagrionidae); four medical snail species, *Biomphalaria alexandrina* Ehrenb, *Bulinus truncatus* Audouin, *Melanoides tuberculata* Muller and *Cleopatra bulimoides* Olivier as shown in Photos 1 to 9 and Table 1.

Calculations

The data of these treatments were analyzed by the program statistical package for social science (SPSS). The mean statistical analysis was performed by Duncan's multiple range tests at 0.05 level of probability (Snedecor and Cochran, 1989).



Photo 1. Adult of *Limnogeton fieberi* Mayr.



Photo 2. Adult of *Sphaerodema urinator* Duf.



Photo 3. Nymph of *Anax imperator* Leach.



Photo 4. Nymph of *Crocothemis erythraea* Brulle.



Photo 5. Nymph of *Ischnura pumilio* charp.

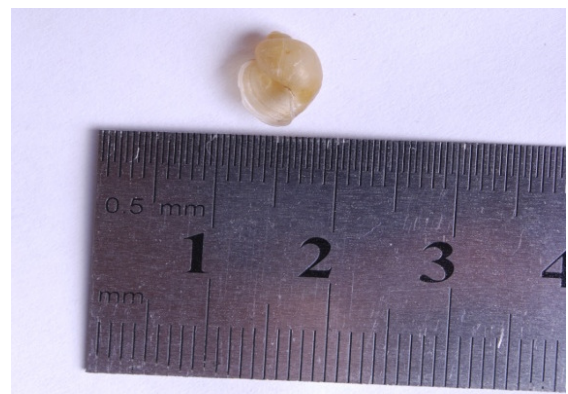


Photo 6. *Bulinus truncates* Audouin.

RESULTS

The present study investigated the effect of four pH values (5, 7, 9 and 11) on consumption capability of five predators (two adult hemipterous species which are *L.*

fieberi Mayr, *S. urinator* Duf. (Belostomatidae) and three nymphal odonatus species, *A. imperator* Leach (Aeshnidae), *C. erythraea* Brulle (Libellulidae) and *I. pumilio* Charp. (Coenagrionidae). The preys were represented by four snail species, *Biomphalaria alexandrina* Ehrenb, *Bulinus truncates* Audouin, *Melanoides tuberculata* Muller

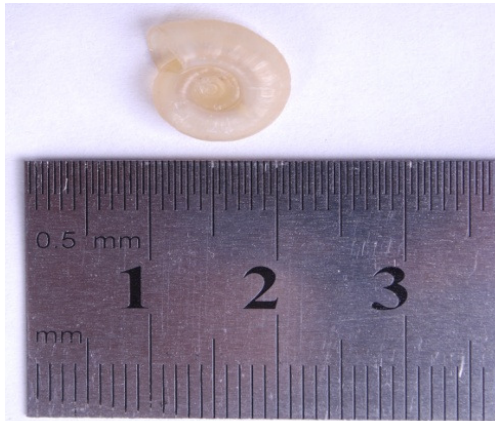


Photo 7. *Biomphalaria alexandrina* Ehrenb.



Photo 8. *Cleopatra bulimoides* Olivier.



Photo 9. *Melanoides tuberculata* Muller.

and *Cleopatra bulimoides* Olivier. The predatory consumption was shown as follows:

Consumption capability of *Limnogeton fieberi* preying four different types of snails under laboratory condition and four pH values

The consumption capability of the heteropteran predator *L. fieberi* preying on each of the four snail species (as preys), *Bulinus truncatus* Audouin, *Biomphalaria alexandrina* Ehrenberg, *Cleopatra bulimoides* Olivier and *Melanoides tuberculata* was examined under four values of pH (5,7,9 and 11) at 30°C in addition to room conditions (Table 2 and Figure 1).

The data showed that, the maximum consumed prey was represented by *B. truncatus* (with mean of $8.96a \pm 0.49$), while the minimum was observed in the case of *C. bulimoides* (mean of $6.30c \pm 0.30$). Meantime, there was no significant difference between the other snails, *B. alexandrina* and *M. tuberculata*. These results were confirmed statistically as highly significance at $P > 0.1\%$ probability level of error for predation of the present predator.

On the other hand, the current study showed a significant high consumption of the preys under both 7 pH and 9 pH. In contrast, the lowest number of eaten snails was under 11 pH. On the other hand, the predation process was the highest under the laboratory condition.

Furthermore, the data illustrated that the predator *L. fieberi* Mayr, preferred the prey *B. truncatus* as the highest consumed prey, but the snail *C. bulimoides* was the least preferable one. In addition, the maximum predation occurred under 7 pH value regardless of the laboratory condition.

However, this predaceous bug *L. fieberi* seems to be the most efficient predator against the four species of snails. It was able to devour all sizes of the snails.

Consumption capability of *S.urinator* preying on four different types of snails under laboratory pH values

Data presented in Table 3 and Figure 2 explain the consumption capability of the belostomatid predator *S. urinator* preying on four types of snails, *B. truncatus*, *B. alexandrina*, *C. bulimoides* and *M. tuberculata* under laboratory condition and four values of pH.

It was clear that, the maximum consumed number of the preys was represented by *B. truncatus* (with mean = $7.71a \pm 0.73$), while the minimum number was observed in the snail *B. alexandrina* (mean = $4.47d \pm 0.34$). These results were confirmed statistically as highly significance at $P > 0.1\%$ probability level of error for predation of the present predator.

On the other hand, the current study show that high consumption of the preys occurred under both pH 7 and 9. Inversely, the lowest number of eaten snails was under pH 11; value shows significant difference.

These result also indicate that the predator *S. urinator*

Table 1. The Hemipterous and odonatous predators preying on four medical snail species under four pH values (5, 7, 9 and 11) at constant temperature 30°C.

| Order | Predator | Prey |
|-----------|--|--------------------------|
| Hemiptera | <i>Limnogeton fieberi</i> Mayr L. | <i>Bulinus truncatus</i> |
| | | <i>B. alexandrina</i> |
| | | <i>M. tuberculata</i> |
| Hemiptera | <i>Sphaerodema urinator</i> Duf.) | <i>C. bulimoide</i> |
| | | <i>Bulinus truncatus</i> |
| | | <i>B. alexandrina</i> |
| Hemiptera | <i>Anax imperator</i> | <i>M. tuberculata</i> |
| | | <i>C. bulimoide</i> |
| | | <i>Bulinus truncatus</i> |
| Odonata | <i>Crocothemis erythraea</i> Brulle C. | <i>B. alexandrina</i> |
| | | <i>M. tuberculata</i> |
| | | <i>C. bulimoide</i> |
| Odonata | <i>Ischnura pumilio</i> Charp | <i>Bulinus truncatus</i> |
| | | <i>B. alexandrina</i> |
| | | <i>M. tuberculata</i> |
| Odonata | | <i>C. bulimoide</i> |

Table 2. Average number of consumed snails by the adult of the predator, *L. fieberi* under laboratory condition and four pH values.

| Consumed snail | Laboratory | pH | | | | Mean | F value |
|-----------------------|---------------------------|-------------------------|-------------------------|------------------------|------------------------|-------------------------|---------|
| | | 5 | 7 | 9 | 11 | | |
| <i>B. truncatus</i> | @17.96 ±0.43 ^A | 4.42± 0.75 ^D | 10.36±1.02 ^B | 9.24±0.59 ^C | 2.82±0.50 ^E | 8.96±0.49 ^a | 758.7** |
| <i>B. alexandrina</i> | 16.76±0.45 ^A | 3.60±0.54 ^C | 7.18±1.31 ^B | 6.98±0.66 ^B | 1.74±0.42 ^D | 7.25±0.29 ^b | 342.1** |
| <i>C. bulimoides</i> | 15.24±0.32 ^A | 3.02±0.58 ^D | 5.20±1.25 ^C | 6.60±0.79 ^B | 1.46±0.30 ^E | 6.30±0.30 ^c | 394.3** |
| <i>M. tuberculata</i> | 16.42±0.36 ^A | 3.40±0.40 ^C | 6.86±1.37 ^B | 6.60±0.78 ^B | 1.68±0.34 ^D | 6.99 ±0.32 ^b | 619.5** |
| Mean | 16.60±1.12 ^A | 3.61±0.59 ^C | 7.40±2.16 ^B | 7.36±1.27 ^B | 1.93±0.61 ^D | | |

F. value: A (snails) = 128.3** B (pH) = 2596.8** AB = 9.38**; @ = Based on (10 days x 5 replicates). F. Test : ns = not significant; * = significant at 5% level of probability; ** = highly significant at 1% level of probability. Means followed by the same letter in each row or column are not significantly different at 0.05 level of probability by Duncan's multiple range test.

Table 3. Average number of consumed snails by the adult of predator *S. urinator* under laboratory condition and four pH values.

| Consumed snail | Laboratory | pH | | | | Mean | F value |
|-----------------------|--------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|----------|
| | | 5 | 7 | 9 | 11 | | |
| <i>B. truncatus</i> | @15.72±0.83 ^A | 3.56±0.96 ^D | 8.98±1.05 ^B | 7.96±1.09 ^C | 2.32±0.41 ^E | 7.71±0.73 ^a | 727.7** |
| <i>B. alexandrina</i> | 11.60±0.25 ^A | 2.24±0.93 ^C | 3.76±0.37 ^B | 3.88±0.44 ^B | 0.88±0.33 ^D | 4.47±0.34 ^d | 1412.3** |
| <i>C. bulimoides</i> | 13.84±0.78 ^A | 2.64±0.85 ^D | 7.00±1.25 ^B | 6.02±0.83 ^C | 1.36±0.43 ^E | 6.17±0.72 ^c | 940.7** |
| <i>M. tuberculata</i> | 15.20±0.54 ^A | 2.90±0.82 ^D | 7.18±1.14 ^B | 5.94±0.65 ^C | 1.68±0.56 ^E | 6.58±0.64 ^b | 1110.3** |
| Mean | 14.09±1.84 ^A | 2.84±0.55 ^D | 6.73±2.17 ^B | 5.95±1.67 ^C | 1.56±0.60 ^E | | |

F. value: A (snails) = 324.2** B (pH) = 3437.1** ; AB = 22.96** ; @ = Based on (10 days x 5 replicates). F. Test : ns = not significant; * = significant at 5% level of probability; ** = highly significant at 1% level of probability. Means followed by the same letter in each row or column are not significantly different at 0.05 level of probability by Duncan's multiple range test.

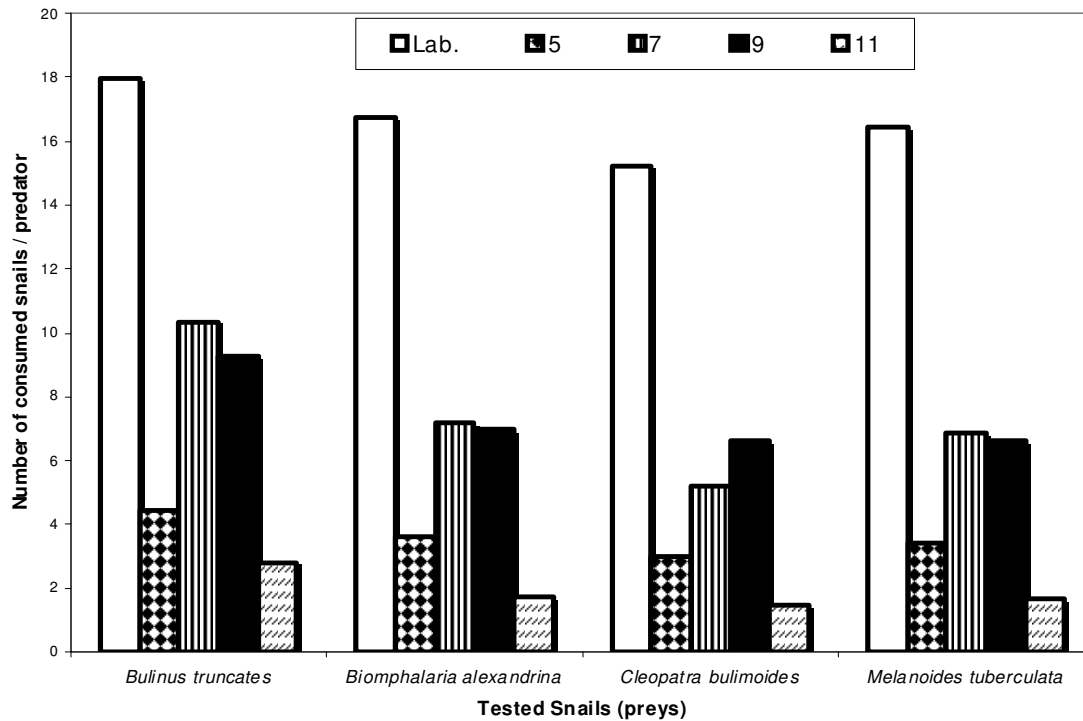


Figure 1. Average number of consumed snails by the adult predator (*Limnogeton fieberi*) under laboratory and four pH values.

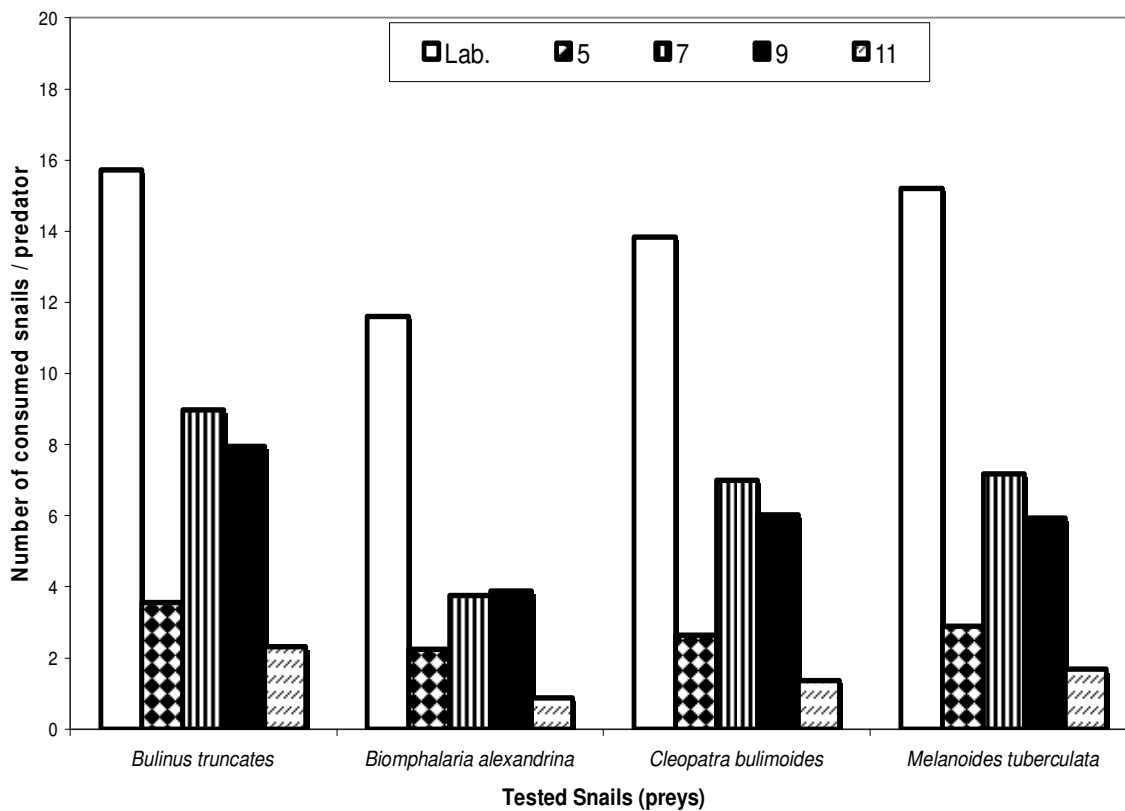
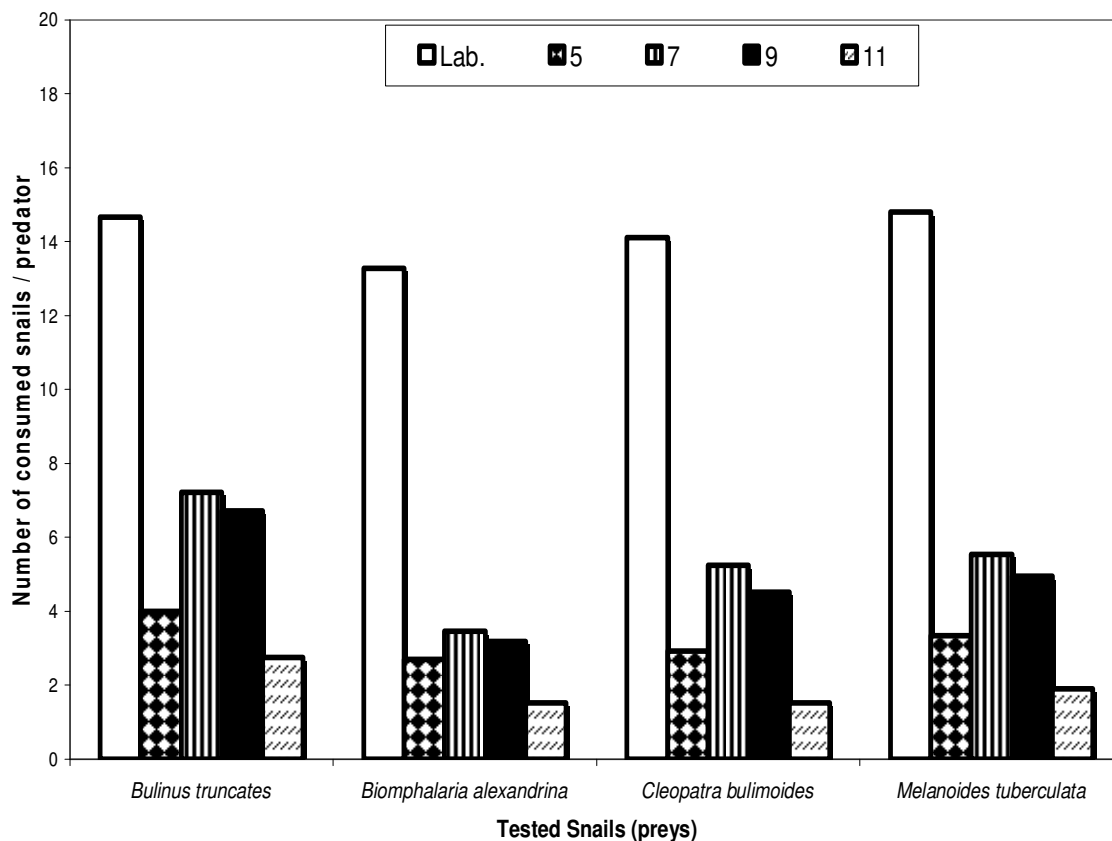


Figure 2. Average number of consumed snails by the adult predator (*Sphaerodema urinator*) under laboratory and four pH values.

Table 4. Average number of consumed snails by the n of predator *A. imperator* under laboratory condition and four pH values.

| Consumed snail | pH | | | | | Mean | F value |
|-----------------------|--------------------------|------------------------|-------------------------|------------------------|------------------------|------------------------|----------|
| | Laboratory | 5 | 7 | 9 | 11 | | |
| <i>B. truncatus</i> | @14.66±0.65 ^A | 4.00±0.6 ^C | 7.22B±0.8 ^B | 6.72±1.03 ^B | 2.74±0.44 ^D | 7.07±0.57 ^a | 1254.8** |
| <i>B. alexandrina</i> | 13.28±0.53 ^A | 2.70±0.69 ^C | 3.46B±0.21 ^B | 3.18±0.33 ^B | 1.52±0.69 ^D | 4.83±0.32 ^d | 1266.3** |
| <i>C. bulimoides</i> | 14.10±0.57 ^A | 2.92±0.67 ^D | 5.24B±0.73 ^B | 4.52±0.62 ^C | 1.52±0.23 ^E | 5.66±0.40 ^c | 1577.1** |
| <i>M. tuberculata</i> | 14.80±0.83 ^A | 3.34±0.61 ^D | 5.54B±0.74 ^B | 4.94±0.53 ^C | 1.90±0.32 ^E | 6.10±0.45 ^b | 2036.1** |
| Mean | 14.21±0.69 ^A | 3.24±0.57 ^D | 5.36B±1.54 ^B | 4.84±1.46 ^C | 1.92±0.58 ^E | | |

F. value: A (snails) = 196.6** B (pH) = 4239.1** ; AB = 14.96** ; @ = Based on (10 days x 5 replicates. F. Test : ns = not significant; * = significant at 5% level of probability; ** = highly significant at 1% level of probability. Means followed by the same letter in each row or column are not significantly different at 0.05 level of probability by Duncan's multiple range test.

**Figure 3.** Average number of consumed snails by the adult predator (*Anax imperator*) under laboratory and four pH values.

preferred *B. truncatus* as the highest consumed preys, while the snail *B. alexandrina* was the lowest preferable one. In addition, these results indicated that the maximum predation was less than 7 pH value, regardless of the laboratory condition.

These results indicate that *S. urinator* was active in the different pH values and showed a predatory activity towards the different types of snails; it preferred the small size of snails.

Consumption capability of *A. imperator* preying on four different types of snails under laboratory condition and four values of pH

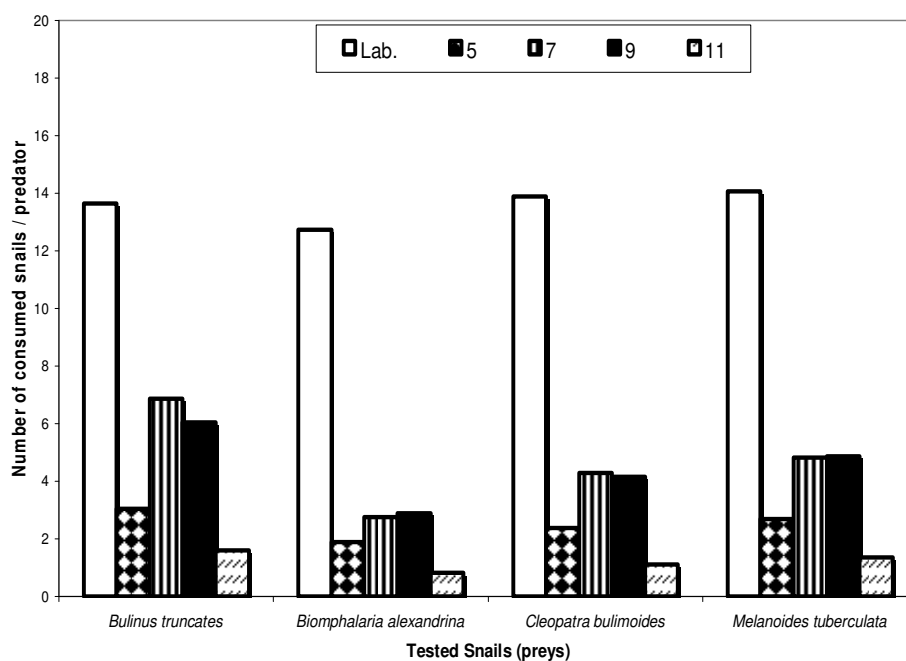
The current work explain the consumption rate of the aeschnid nymphs of *A. imperator* Leach (the predator) feeding on four types of snails under laboratory condition and four pH values at 30°C (Table 4 and Figure 3).

Regarding the comparison between the consumed

Table 5. Average number of consumed snails by the nymph of predator (*C. erythraea*) under laboratory condition and four pH values.

| Consumed snail | pH | | | | | Mean | F value |
|-----------------------|--------------------------|-------------------------|--------------------------------------|------------------------|------------------------|------------------------|----------|
| | Laboratory | 5 | 7 | 9 | 11 | | |
| <i>B. truncatus</i> | @13.66±0.86 ^A | 3.06±0.85 ^D | 6.88 ^B ±0.83 ^B | 6.04±0.72 ^C | 1.62±0.26 ^E | 6.25±0.62 ^a | 1086.9** |
| <i>B. alexandrina</i> | 12.74±0.49 ^A | 1.90C±0.65 ^C | 2.76±0.36 ^B | 2.90±0.46 ^B | 0.82±0.30 ^D | 4.22±0.41 ^d | 1392.5** |
| <i>C. bulimoides</i> | 13.90±0.37 ^A | 2.38C±0.72 ^C | 4.30±1.16 ^B | 4.16±0.76 ^B | 1.12±0.37 ^D | 5.17±0.61 ^c | 1097.2** |
| <i>M. tuberculata</i> | 14.08±0.84 ^A | 2.70±0.80 ^C | 4.84±0.83 ^B | 4.88±0.58 ^B | 1.36±0.39 ^D | 5.57±0.63 ^b | 1997.0** |
| Mean | 13.60±0.60 ^A | 2.51±0.49 ^D | 4.70±1.70 ^B | 4.50±1.32 ^C | 1.23±0.34 ^E | | |

F. value: A (snails) = 223.6.6** B (pH) = 5864.4** ; AB = 27.27** ; @ = Based on (10 days x 5 replicates. F. Test: ns = not significant; * = significant at 5% level of probability; ** = highly significant at 1% level of probability. Means followed by the same letter in each row or column are not significantly different at 0.05 level of probability by Duncan's multiple range test.

**Figure 4.** Average number of consumed snails by the adult predator (*C. erythraea*) under laboratory and four pH values.

snails, it was found that the maximum consumed number of the preys was represented by *B. truncatus* (mean = 7.07 ± 0.57), while the minimum number was observed in the case of the snail *B. alexandrina* (mean = 4.83 ± 0.32).

These results were confirmed statistically as highly significance at $p > 0.1\%$ probability level of error for predation of the present predator.

On the other hand, the current study shows that high consumption of the preys occurred under 7pH value. In contrast, the lowest number of eaten snails was under pH 11 value, as the statistical analysis confirmed this result. However, the predation process was in the maximum activity under the laboratory conditions. The same result indicate that the predator *A. imperator* preferred *B. truncatus* as the highest consumed preys, while the snail *B. alexandrina* was the lowest one. In addition, these

results indicated that the maximum predation was under 7pH value regardless of the laboratory condition. These results indicate that the *Anax imperator* was active in the different pH values and showed a predatory activity upon different types of snails.

Consumption capability of *C. erythraea* preying on four different types of snails under laboratory condition and four pH values

The consumption capability of the aeschnid nymphs of *Crocothemis erythraea* preying on four types of snails, *B. truncatus*, *B. alexandrina*, *C. bulimoides* and *M. tuberculata* under laboratory condition and four pH values at 30°C is shown in Table 5 and Figure 4.

Table 6. Average number of consumed snails by the nymph of the predator *I. pumilio* under laboratory condition and four pH values.

| Consumed snail | pH | | | | | Mean | F value |
|-----------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|----------------------|
| | Laboratory | 5 | 7 | 9 | 11 | | |
| <i>B. truncatus</i> | 9.66±0.77 ^A | 2.24±0.89 ^C | 5.54±0.85 ^B | 4.92±0.67 ^B | 0.56±0.13 ^D | 4.58±0.56 ^a | 834.4 ^{**} |
| <i>B. alexandrina</i> | 8.86±0.69 ^A | 1.96±1.21 ^B | 1.84±0.25 ^B | 1.48±0.32 ^C | 0.18±0.11 ^D | 2.86±0.48 ^d | 888.8 ^{**} |
| <i>C. bulimoides</i> | 9.32±0.99 ^A | 1.80±0.68 ^C | 2.82±0.58 ^B | 2.42±0.46 ^B | 0.22±0.15 ^D | 3.32±0.48 ^c | 1109.2 ^{**} |
| <i>M. tuberculata</i> | 9.38±0.67 ^A | 1.86±0.86 ^C | 4.50±0.74 ^B | 4.20±0.74 ^B | 0.30±0.11 ^D | 4.05±0.54 ^b | 1135.2 ^{**} |
| Mean | 9.31±0.33 ^A | 1.97±0.19 ^D | 3.68±1.66 ^B | 3.26±1.58 ^C | 0.32±0.17 ^E | | |

F. value: A (snails) = 141.3^{**} B (pH) = 2233.1^{**}; AB = 30.52^{**}; [®] = Based on (10 days x 5 replicates). F. Test: ns = not significant; * = significant at 5% level of probability; ** = highly significant at 1% level of probability. Means followed by the same letter in each row or column are not significantly different at 0.05 level of probability by Duncan's multiple range test.

Regarding the comparison between the consumed snails, it was found that the maximum consumed number of the preys was represented by *B. truncatus* (mean = 6.25 ± 0.62), while the minimum number was observed in the case of the snail *B. alexandrina* (mean = 4.22 ± 0.41). These results were confirmed statistically as highly significance at p > 0.1% probability level of error for predation of the present predator.

On the other hand, the current study shows high consumption of the preys under pH 7. In contrast, the lowest number of eaten snails was under pH 11; the statistical analysis of the influence of the different pH values on *C. erythraea* activity supported this result.

In addition, maximum statistic significance was registered to affect both snail varieties and the different pH values, collectively. However, the predation process was in maximal activity under the laboratory conditions.

Thereby, the result also indicates that the predator *C. erythraea* preferred *B. truncatus* as the highest consumed preys, while the snail *B. alexandrina* was the least one. In addition, these results indicate that the maximum predation was under pH 7 regardless of the laboratory condition.

So, these results indicate that the intense and active predation by the dragon fly *Crocothemis erythraea* was on the different types and different sizes of snails. The efficiency of this nymph in predating snails was less than that of the aforementioned species (that is, *Anax imperator*).

Consumption capability of *I. pumilio* preying on different four types of snails under laboratory condition and four pH values

The consumption capability of the agrionid nymphs of *I. pumilio* preying on four types of snails, *B. truncatus*, *B. alexandrina*, *C. bulimoides* and *M. tuberculata*, under laboratory condition and four values of pH at 30°C is shown in Table 6 and Figure 5. Regarding the comparison between the consumed snails, it was found that the maximum consumed number of the preys was represent-

ed by *B. truncates* (mean = 4.58 ± 0.56), while the minimum number was observed in the case of the snail *B. alexandrina* (mean = 2.86d ± 0.48). These results were confirmed statistically as highly significance at P > 0.1% probability level of error for predation of the present predator.

On the other hand, the present study showed that the highest consumption of the preys was under pH 7. In contrast, the lowest number of eaten snails was under pH 11. The statistical analysis confirmed this result. In addition, maximum statistic significance was registered to affect both snail varieties and the different pH values collectively. However, the predation process was in the maximum activity under the laboratory conditions.

Thereby, the last result indicate that the predator *I. pumilio* preferred *B. truncatus* as the highest consumed preys, while it showed the lowest consumption with the snail *B. alexandrina*. In addition, these results indicate that the maximum predation occurred under pH 7 regardless the laboratory conditions.

So, these results indicate that the intense and active predation by dragon fly, *I. pumilio* was on small size snails. The efficiency of this nymph in predating snails was less than that of the aforementioned species (that is, *C. erythraea*).

Consumption capability of five predators preying on four different types of snails under laboratory condition and four pH values:

Data given in Table 7 and Figure 6 compared the consumption capability of five insects (as predators), *L. fieberi*, *S. urinator*, *A. imperator*, *C. erythraea* and *I. pumilio* feeding on four snail species (as preys), *B. truncates*, *B. alexandrina*, *C. bulimoides* and *M. tuberculata* under four values of pH at 30°C in addition to room conditions.

The data showed high consumption of the preys by the all aforementioned predator species under pH 7 except, *L. fieberi* which showed high consumption of the preys under both pH 7 and 9. In contrast, the lowest number of

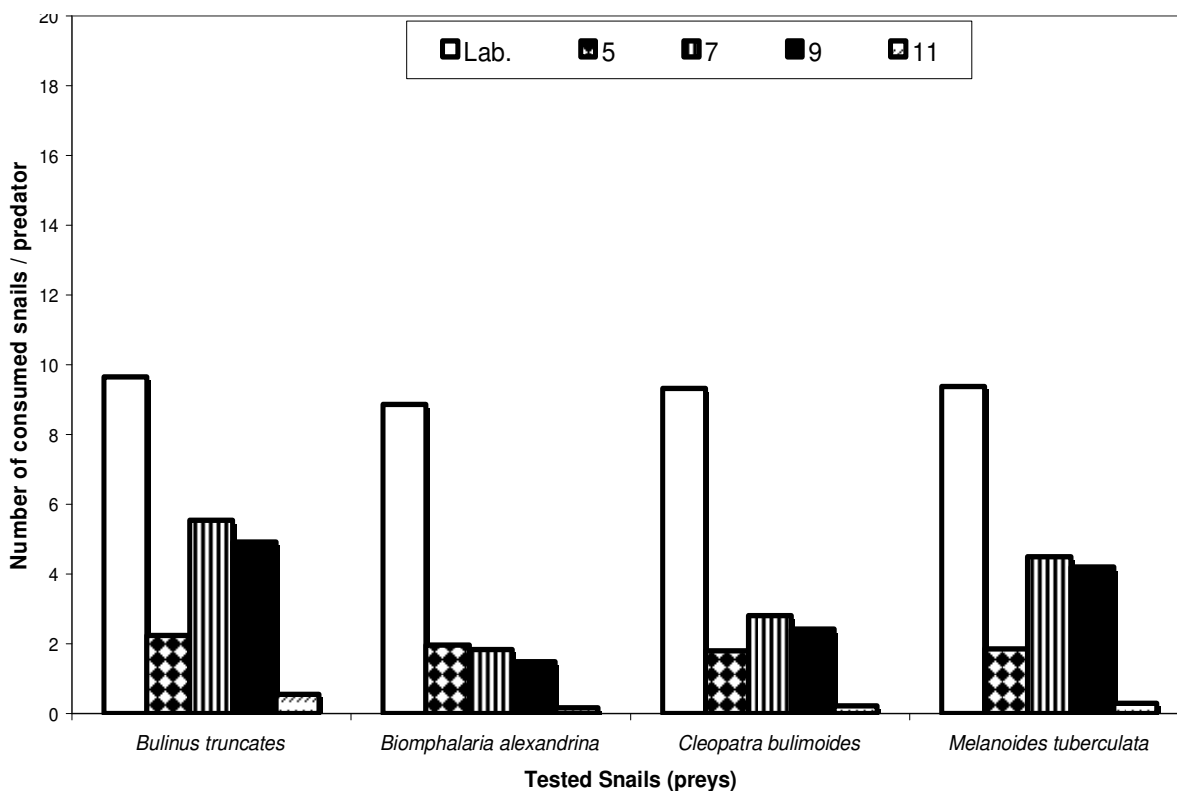


Figure 5. Average number of consumed snails by the adult predator (*Ischnura pumilio*) under laboratory and four pH values.

Table 7. Average number of consumed snails by five different predators under laboratory condition and four pH values.

| pH | Predator | | | | |
|------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| | <i>L. fieberi</i> | <i>S. urinator</i> | <i>imperator</i> | <i>C. erythraea</i> | <i>I. pumilio</i> |
| Laboratory | 16.60 ± 1.12 ^A | 14.09 ± 1.84 ^A | 14.21 ± 0.69 ^A | 13.60 ± 0.60 ^A | 9.31 ± 0.33 ^A |
| 5 | 3.61 ± 0.59 ^C | 2.84 ± 0.55 ^D | 3.24 ± 0.57 ^D | 2.51 ± 0.49 ^D | 1.97 ± 0.19 ^D |
| 7 | 7.40 ± 2.16 ^B | 6.73 ± 2.73 ^B | 5.36 ± 1.54 ^B | 4.70 ± 1.70 ^B | 3.68 ± 1.66 ^B |
| 9 | 7.36 ± 1.27 ^B | 5.95 ± 1.67 ^C | 4.84 ± 1.46 ^C | 4.50 ± 1.32 ^C | 3.26 ± 1.58 ^C |
| 11 | 1.93 ± 0.61 ^D | 1.56 ± 0.60 ^E | 1.92 ± 0.58 ^E | 1.23 ± 0.34 ^E | 0.32 ± 0.17 ^E |

Based on (10 days x 5 replicates. F. Test: ns = not significant; * = significant at 5% level of probability; ** = highly significant at 1% level of probability. Means followed by the same letter in each row or column are not significantly different at 0.05 level of probability by Duncan's multiple range test.

eaten snails was under pH 11. This result was confirmed statistically. However, the predation process was in the maximum activity under the laboratory conditions.

The result indicate that the predator *L. fieberi* had highly predatory efficiency of consumption capacity under the different pH values, while the lowest predatory efficiency of consumption capacity happened with *I. pumilio*. In addition, these results indicate that the maximum predation was under pH 7 regardless of the laboratory condition.

These results indicate that all predators were active in the different pH values and had the ability of consumption

of the different types of snails.

DISCUSSION

The present work tried to make interpretation to the consumption capability of five predators (*L. fieberi*, *S. urinator*, *Anax imperator* Leach, *C. erythraea* Brulle and *I. pumilio* Charp.) under laboratory and four pH values (5, 7, 9, and 11) at constant temperature (30°C) on four species of snails (*B. truncatus*, *B. alexandrina*, *C. bulimoides* and *M. tuberculata*). Changes in pH value of water are important to many organisms. Most organisms have

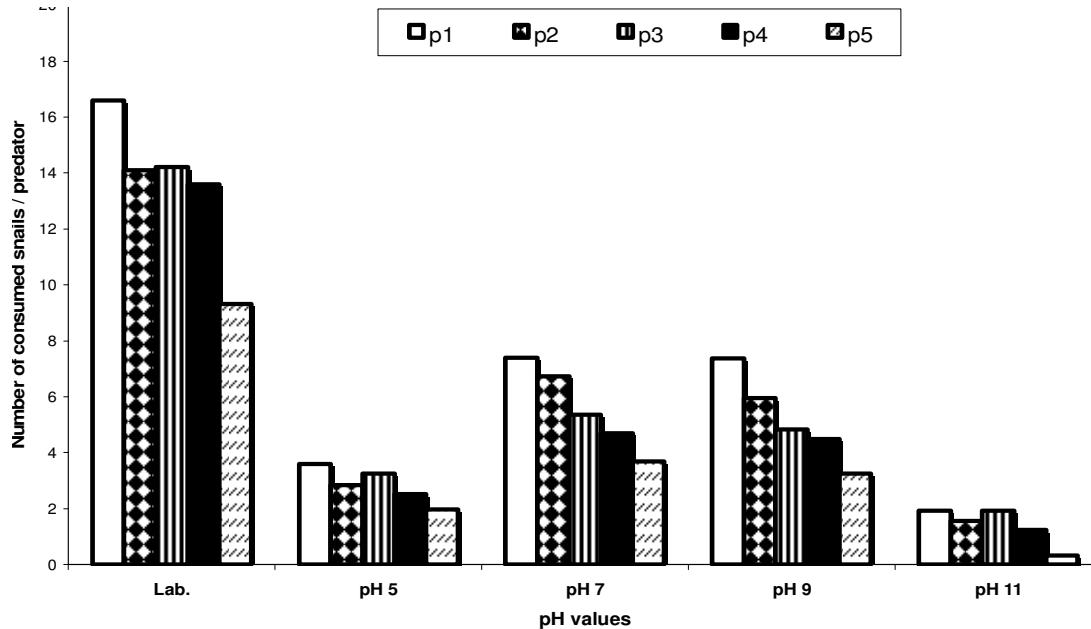


Figure 6. Average number of consumed snails by the five different predators under laboratory and four pH values. p1 = *Limnogeton fieberi*; p2 = *Sphaerodema urinate*; p3 = *Anax imperator*; p4 = *Crocothemis erythraea*; p5 = *Ischnura pumilio*.

adapted to life in water of a specific pH and may die if it changes even slightly.

Mechanism of the chemical component for adjusting water pH

In fact, if pH value gets high, ammonia toxicity increases. Then, the water hardness also increases. There are more dissolved minerals in the water. This creates a buffer effect which prevents reduction in pH. In contrast, if pH levels get to low, water can leach metal ions from plumbing and filters.

Consumption capability of *L. fieberi* preying on different types of snails under laboratory condition and four pH values

The data in the results may be referred to *L. fieberi* that attacked the four types of snails, but the maximum consumed number of the preys was represented by *B. truncates*, while the minimum number was observed in the case of the snail *C. bulimoides* large Belostoma species. That may mean that the present belostomatid predator prefers feeding on *B. truncates*, while it considers *C. bulimoides* as the last choice for feeding. These results agree with Reyes and Estevez (2006) who, stated that all of the Belostomatidae family members have forelegs adapted to catch prey which are usually ambushed by bugs. After catching prey, bugs handle it in

order to insert their piercing mouth parts to inject saliva and liquefy prey's tissues to suck.

On the other hand, the current study exhibit high consumption of the preys under both pH 7 and 9 (there was no significant differences between them). This result could mean that the pH values (7 and 9 pH values) were close to that of values in nature. In contrast, the lowest number of consumed snails was under pH 11 at constant temperature (30°C). Physiologically, the total process of metabolism may be affected by the suffer water alkaline media. Mathematically, the statistical analysis of the data on the influence of the different pH values on *L. fieberi* activity supported this result because F value proved highly significance on pH on the predation process.

Consumption capability of *S. urinator* preying on different types of snails under laboratory condition and four pH values

Interpretation of the results indicate that the *S. urinator* attacked and consumed the four types of snails, but the maximum consumed number of the preys was represented by *B. truncates*, while the minimum number was observed in snail *B. alexandrina*. The same result was obtained by Osman (2001) who reported that the biological factors were represented by predated one belostomatid species (*S. urinator*) on two medical snails (*B. truncatus* and *B. alexandrina*). The results revealed the successful control of *B. truncates* by *S. urinator*, while this predator failed to control *B. alexandrina*.

On the other hand, the current study indicates high consumption of the preys under 7 pH value (highly significance). This pH value is close to the value in nature.

In contrast, the lowest number of consumption of the preys under 11 pH value at constant temperature (30 °C). The statistical analysis on the influence of the different pH values on *L. fieberi* activity supported this result because F. value proved highly significance of pH on the predation process.

Success of *Belostoma* species individuals to prey snails perhaps due to the specialized characteristics of their head such as the presence of anteoculus which is longer than their interoculus, in addition to a slender and long beak enabling the stylets to be inserted deeper into the shells. Thus this long beak reaches the retracted body of *Biomphalaria*. These interpretations were supported by Reyes and Estevez (2006). Thereby, *S. urinator* was active in the different pH values and showed a predatory activity on different types of snails; it prefer the small size of snails.

Consumption capability of *A. imperator* preying on different types of snails under laboratory condition and four pH values

The predator *A. imperator* also preferred *B. truncates* as the highest consumed preys, while it showed the lowest consumption with the snail *B. alexandrina*. This may be because of the nymphs of *Anax imperator*. They made predation upon *B. truncates* more easily than upon *B. alexandrina*. The aperture of the former species was wide and suits the penetrating mouth parts which made it reach the animal inside the shell. This result agrees with that of Kesler and Munns (1989). They added that sometimes *Biomphalaria alexandrina* snails could be attacked and killed.

In addition, these results indicate maximum predation under pH 7. In contrast, the lowest number of consumption of the preys was under pH 11 at constant temperature (30 °C). The statistical analysis on the influence of the different pH values on *A. imperator* activity supported this result because F value proved highly significance on the predation process.

These results indicate that the *Anax imperator* was active in the different pH values and showed a predatory activity upon different types of snails. These results agree with the results of Hamad et al. (1991), who showed that *A. imperator* manifested the highest efficiency as a predator of mosquito larvae was followed by *S. urinator*, *C. erythraea*, *R. vivina* and *E. vanso-mereni* and agree with Punzo (1988) results who determined the combined effects of low environmental pH and temperature on embryonic survival capacity and metabolic rates in the dragonfly, *Anax junius* Drury. Over a pH range of 3.0-5.0, a water temperature of 30 °C was found to be severely limiting. Over a pH range of 6.0-7.0, hatching success was greater than 80% at the test temperatures ranging

from 10 to 25 °C.

Consumption capability of *C. erythraea* preying on different types of snails under laboratory condition and four pH values

The predator *C. erythraea* preferred *B. truncates* as the highest consumed preys, while the lowest consumption was with the snail *B. alexandrina*. The aperture of the former species was wide and suited the penetrating mouth parts to reach the animal inside the shell. Some times *B. alexandrina* snails could be attacked and killed.

In addition, results indicate the maximum predation under pH 7. In contrast, the lowest number of consumption of the preys under pH 11 at constant temperature (30 °C). These results agree with the results of Hudson and Berrill (1986). The last authors studied the development times and hatching success of the eggs of the four species of Odonata (*Ischnura verticalis*, *Lestes congener*, *Libellula lydia*, and *Sympetrum vicinum*) and found that they were unaffected by exposure to soft water at pH 5.1 and 3.5. Tolerance of low pH, soft water conditions by Odonata eggs may in part account for the widespread distribution of Odonata in potentially acid-stressed regions.

So, these results indicate the intense and active predation by dragon flies (*C. erythraea*) on different types and sizes of snails. The efficiency of this nymph for predating snails was less than that of the mentioned species such as *Anax imperator*.

Consumption capability of *I. pumilio* preying on different types of snails under laboratory condition and four pH values

The result perhaps mean that the predator *Ischnura pumilio* prefers feeding on the prey *Bulinus truncates*. Then, the highest consumption preys was the mentioned snail species. Inversely, that predator species probably deny the snail *Biomphalaria* as prey. The lowest consumption was with *alexandrina*. These results were confirmed statistically as highly significance at $P > 0.1\%$ probability level of error for predation of the present predator. In addition, the results indicate that the maximum predation was under 7 pH. In contrast, the lowest number of consumption of the preys was under pH 11 at constant temperature (30 °C). These results disagree with the results of Standeven (1988), who studied the growth and mortality rates of damselfly nymphs (Agrionidae) maintained for ten weeks at different pH levels and aluminum ion concentrations were compared. It was found that nymphs at pH 4, 5 and 6 actually grew faster than those at pH 7. Henry (1971) tested the effect of low pH on the mature larvae and nymphs of nine species of aquatic insects (dragonflies, stoneflies, caddisflies, and mayfly) in the laboratory at pH values from 1.0 to 7.0. The TL_{50} values (pH at which 50 per cent of the organisms died) at

30 days ranged from pH 2.45 (*Brachycentrus americanus*) to pH 5.38 (*Ephemerella subvaria*). The range at which 50 per cent of the insects emerged was pH 4.0–5.9. The nine species tested were all more sensitive to low pH during the period of emergence.

Thus, it may appear that the Odonata nymphs are able to consume harmful snails, and the species of Odonata nymphs considered in the present study can effectively be used as biological control agents against the snails.

Consumption capability of five predators preying on different four types of snails under laboratory condition and four values of pH

Depending on the result of comparison between the consumption capability of the five insects (as predators), *L. fieberi*, *S. urinator*, *A. imperator*, *C. erythraea* and *I. pumilio* on the four snails species (as preys) which exist in its natural habitat (*B. truncates*, *B. alexandrina*, *C. bulimoides* and *M. tuberculata*) under four values of pH in addition to room conditions, it could be recorded that: The predator *L. fieberi* had highly predatory efficiency of consumption capacity under the different pH values, followed by *S. urinator*, *A. imperator*, and *C. erythraea* while the lowest predatory efficiency of consumption, capacity was found in *Ischnura pumilio*. Therefore, Aeschnid nymphs of *Anax imperator* appeared to be more efficient than those of *Crocothemis erythraea* and *I. pumilio*; all preferred the ovate and acuminate shells. On the other hand, agrionid nymphs of *I. pumilio* preferred attacking the small sizes of snails especially those of the ovate shell. Also, the results show that the maximum predation was at 7 pH, but the lowest number of consumed preys was enrolled under pH 11 at constant temperature (30°C). Moreover, the maximum predation occurred under pH 7 and 9 at 30°C regardless the laboratory conditions. *Limnogeton fieberi* Mayr may well be employed in controlling these snails since successful biological control depends on the selection of a natural enemy having high degree of host specificity or preference. The second successful predators was *I. pumilio* Charp; controlled these snails but was lower than the other predators under four pH values.

The Belostomatidae (*Limnogeton fieberi* and *Sphaerodema urinator*), and Odonata (*Anax imperator*, *Crocothemis erythraea* and *Ischnura pumilio*), could be successful predators on the harmful snails (*Bulinus truncates*, *Melanoides tuberculata*, *Biomphalaria alexandrina* and *Cleopatra bulimoides*). Thus, they are recommended to be reared in large numbers and then released in the breeding places of snails in nature to achieve biological control of these hosts. The results of such studies would enable us to formulate the biological control programme in a more effective way.

Putting a predator in close contact with its preys in a polluted controllable determinative place such as a little

bowl in the laboratory does not give an insured indication that this predator may attack and feed upon the concerned prey in nature (Baldwin et al. 1955; Bates, 1965; Bay, 1974).

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