Journal of Advanced Zoology
ISSN: 0253-7214
Volume 43 Issue 1 Year 2022 Page 1579-1587

Predatory Efficiency of *Notonecta* Spp. And Percent Survivability of Spawn and Fry of Indian Major Carps

Brijesh Chahar[1]*, Tejpal Dahiya[1]

[1]*Department of Zoology, CCS Haryana Agricultural University, Hisar- 125004, Haryana, India*

***Corresponding Author:** Brijesh Chahar*
**Email: brijeshchahar71608@gmail.com*

Abstract

The present investigation was conducted in laboratory under controlled conditions of temperature to determine the predatory efficiency of *Notonecta* spp. (commonly called backswimmers) on Indian Major Carps. Experiment was conducted under two sets of different development stages *i.e.* spawn and fry of Catla, Rohu and Mrigal with a fix number of *Notonecta* in triplicates. After fix duration of experiment, spawn and fry were harvested and observed for morphological alterations. The predatory efficiency of *Notonecta* spp. and percent survivability of spawn and fry of IMC was calculated at the end of experiment. The highest predation rate of *Notonecta* spp. (2.19) was observed on Mrigal spawn at lowest spawn density, followed by Rohu spawn and lowest predation rate (1.38) was observed on Catla spawn at minimum spawn density. In case of IMC fry, the highest predation rate of *Notonecta* (2.19) was observed on Mrigal fry at lowest fry density, followed by Rohu fry and lowest predation rate (1.38) was observed on Catla fry at minimum fry density.

Keywords: Notonecta spp., Predatory efficiency, Morphology, Fry, Fingerlings

Introduction

The majority of aquatic insects in their larval or adult stages, feed on fish hatchlings or fry and compete with them for food due to their diverse feeding habits. The bugs and beetles as the two most prevalent predatory insects (Sigutova *et al.*, 2022). *Cybister*, *Gyrinus*, and *Sternolophus* are beetles that significantly harm young fishes. The aquatic bugs are extremely predatory and have the ability to harm fingerlings. These predatory insects have a high destructive role in fish nurseries (Tripathi & Sharaf, 1975). Backswimmers (Notonectidae), of which the *Anisops* is a classic example, cause the most depredations (Weterings *et al.*, 2014). *Notonecta* spp. show predation on carp spawn and fry with the help of their piercing mouth parts and extract the body fluids from fish, in a diverse range of freshwater environments (Berchi *et al.*, 2023). These predators are rather large and actively swim. The order Hemiptera includes the family Notonectidae within the section Hydrocorisae. This family of insects is sometimes known as greater water boatmen or backswimmers. Backswimmers is the popular term for notonectids, as they swim by pushing their belly up through the water. These insects are referred to as bugs which are little to medium-sized with piercing and sucking mouthparts. The *Notonecta* spp. lay eggs in the autumn or spring (depending on the species) and reproduce only once a year (Briers, 1999). The adults are brown or dull grey in color, about 14–17 mm in length (Reynaldi *et al.*, 2011). While fish eggs, fry, and tadpoles also have been reported as prey for *Notonecta* spp. (Gonzalez & Leal, 1995). It has been observed that *Notonecta glauca* feeds on the larvae of the *Culex pipens* mosquito (Reynaldi *et al.*, 2011). The raptorial forelegs or middle legs contain grabbing surfaces that make it difficult for prey to escape away, the common backswimmer uses these legs to capture its prey during hunting (Giller & McNeill, 1981). It has been shown that backswimmers favor larger zooplankton species in experimental conditions (Domingos *et al.*, 2016). The "sit and wait" predators known as backswimmers remain in the water column, waiting for prey to approach closely (Martin & Lopez, 2004). Specialized eyes like binoculars help backswimmers to locate and apprehend prey (Land, 1980). These are external feeders that puncture their victim with their beaks to inject paralyzing fluid into it before removing its body fluids (Griffith & Gillett- Kauffman, 2021). The *Notonecta* spp. are found below the water surface rather than at the surface. *N. glauca* remains submerged when the air temperature is below 15°C (59°F). These species spend more time on the water surface above 15°C (59°F). It prefers to remain fully immersed at 5°C (41°F). The common backswimmer prefers to remain underwater at higher temperatures (Cockrell, 1984).

Materials and Methods

(a) Procurement and maintenance of *Notonecta* spp.

Adult *Notonecta* spp. were procured from the Aquacultural Research Training Institute, Hisar, and transported to the experimental site in the oxygen filled plastic bags followed by their disinfection with $KMnO_4$ solution. The insects were allowed to acclimatize for fifteen days in single large rectangular fiber tank with a capacity of 200 litres, and were provided with proper aeration from an aerator. The insect species were collected with an insect net of 200µ mesh size, from time to time during the experiment and maintained in the experimental laboratory within separate experimentation tanks with approximately 30 litres of pond water, each tank contained a maximum of 15 adult *Notonecta* spp. The insects were fed with dead fry and fish feed pellets. The water was exchanged daily to remove dead insects and feed was supplied every alternate day. The test insects were maintained in the laboratory under appropriate conditions of temperature varying from 25 - 30°C. The experiment was carried out under controlled conditions in laboratory. The acclimatized insects were used for the current investigation.

(b) Calculation of Predatory Efficiency:

In the present investigation, a fix number (5 insects per treatment) of *Notonecta* spp. were released and each experiment was replicated three times in experimentation tanks. Spawn and fry of IMC were taken as control. After one-hour duration, spawn and fry were harvested from tanks and observed for morphological alterations. The number of carp spawn or fry destroyed by *Notonecta* spp. were noted for one hour. This experiment was repeated five times after the gap of 24 hrs. and mean mortality of spawn/fry was calculated. The predatory efficiency of *Notonecta* spp. on different prey densities (10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60 spawn/80L) and percent survivability of spawn and fry of IMC were calculated after completion of experiment.

$$\textbf{Predatory efficiency: } \frac{\text{No. of fish consumed}}{\text{Time interval (hr)}} \times 100$$

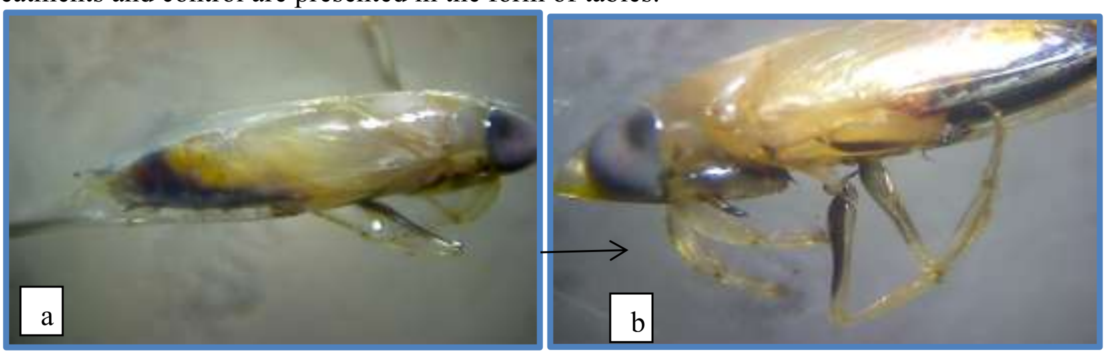
$$\textbf{\% Survival rate: } \frac{\text{Total number of fishes harvested}}{\text{Total number of fishes stocked}} \times 100$$

Statistical analysis:

Data obtained during the experimental period was analysed by OPSTAT software using one way and two-way ANOVA. Results were expressed as mean ± SE. Tukey's multiple range test was used to compare the mean differences.

Results

The predatory efficiency of *Notonecta* spp. and percent survivability of spawn and fry of Indian Major Carps in the treatments and control are presented in the form of tables.



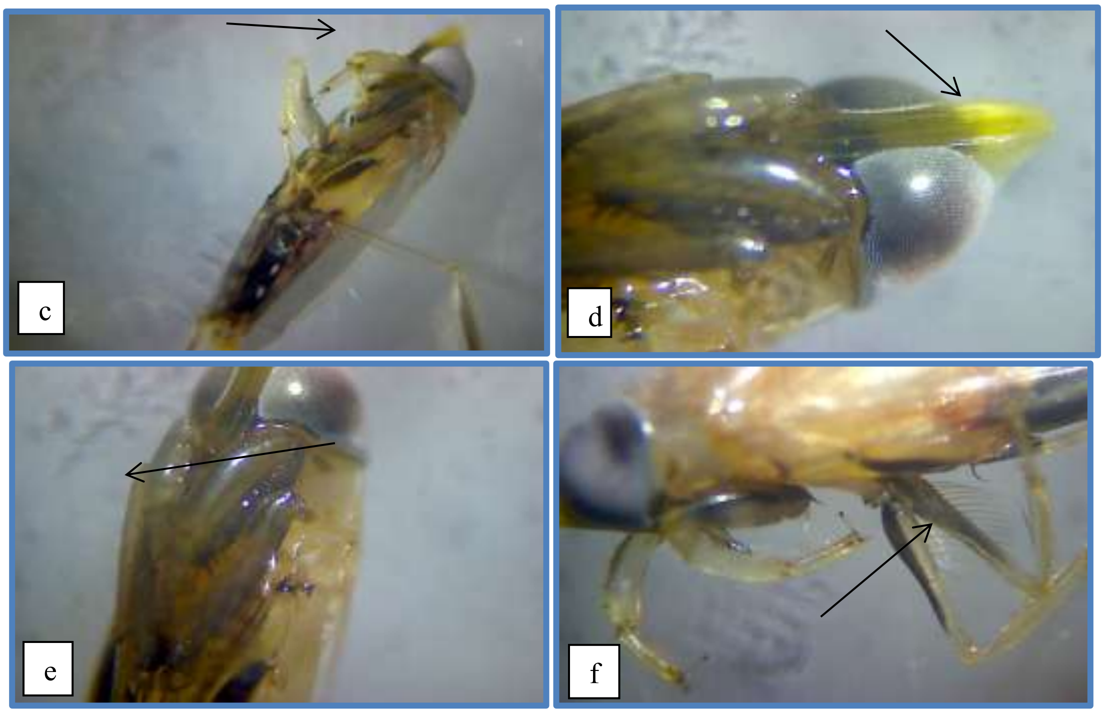


Figure 1. (**a**) Adult *Notonecta* sp. (**b**) Femur of *Notonecta*, (**c**) Antenna of *Notonecta*, (**d**) Rostrum of *Notonecta,* (**e**) Pronotal furrow of *Notonecta*, (**f**) Lower palar row of setae of *Notonecta*

(a) Predatory efficiency of *Notonecta* spp. on Catla spawn:

The mean predatory efficiency of *Notonecta* spp. on Catla spawn was significantly higher in the treatment's groups ($p<0.01$) as compared to the control groups (without *Notonecta*) during the experimental period. The minimum rate of predation was observed at low spawn density. The initial mean predatory efficiency of *Notonecta* spp. was similar in all different observation day groups. The mean values of predatory efficiency were increased from 1.38 N/hr to 11.51 N/hr as the spawn density increased. However, % survivability of fish was reduced from 86.6% to 14.6% with the increase in predatory efficiency (Table 1). The maximum predatory efficiency was reported on 5th day group (6.65 N/hr), followed by 2nd day group (6.63 N/hr), 1st day group (6.58 N/hr), 4th day group (6.51 N/hr) and 3rd day group (6.50 N/hr). According to ANOVA table, both the spawn density and the observation days significantly ($p=0$) affected the predatory efficiency of *Notonecta* spp.

Table 1: Predatory efficiency of *Notonecta* spp. on Catla spawn and percent survivability of Catla spawn

Spawn density (No. of spawn / 80 L)	Predatory efficiency (N/hr) of *Notonecta* spp. on Catla spawn						
	1d	2d	3d	4d	5d	Predatory efficiency (N/hr)	% survivability
10	1.40±0.50	1.39±0.48	1.39±0.86	1.37±0.35	1.35±0.24	1.38	86.60
15	2.35±0.76	2.33±0.66	2.42±0.87	2.31±0.12	2.30±0.05	2.34	82.66
20	3.4±0.50	3.31±0.34	3.25±0.06	3.11±0.12	4.0±0.45	3.41	76.00
25	4.53±0.68	4.52±.11	4.51±0.13	3.48±0.34	4.67±0.65	4.34	69.33
30	5.66±0.21	5.65±0.34	4.64±0.56	5.61±0.12	5.58±0.08	5.42	62.66
35	6.73±0.45	6.71±0.33	5.70±0.92	6.86±0.34	6.62±0.11	6.52	56.00
40	7.73±0.66	7.71±0.46	7.68±0.76	8.64±0.45	8.61±0.12	8.07	49.30
45	8.8±0.41	9.6±0.12	8.5±0.56	9.34±0.54	8.28±0.54	8.91	36.00
50	9.73±0.55	9.68±0.54	8.44±0.22	9.32±0.22	9.00±0.88	9.23	28.00
55	10.66±0.45	10.58±0.11	11.49±0.55	10.22±0.11	11.05±0.11	10.4	21.30
60	11.54±0.32	11.54±0.22	11.45±0.03	11.31±0.56	11.70±0.14	11.51	14.66
Mean	6.58	6.63	6.50	6.51	6.65		

Two-way Anova	C.D.	SE (m)	Df	F - value
Treatment	0.115	0.041	10	6,235.113
Days	0.074	0.026	4	14.947
Treatment × Days	0.536	0.091	40	1.217

(b) Predatory efficiency of *Notonecta* spp. on Rohu spawn and percent survivability of Rohu spawn:
The observation day groups had a considerably higher mean predatory efficiency of *Notonecta* spp. on Rohu spawn ($p<0.01$) compared to the control group (without *Notonecta*) was observed. At the lowest spawn density, the predation rate was found minimum. With an increase in spawn density, the average predatory efficiency values of *Notonecta* spp. increased from 2.19 N/hr to 12.53 N/hr. However, the reduction in % survivability of fish was observed from 85.4% to 14.12% with the increase in predatory efficiency (Table 2). The maximum predatory efficiency was reported on 1st day group (7.72 N/hr), followed by 2nd day group (7.64 N/hr), 4th day group (7.22 N/hr), 5th day group (7.13 N/hr) and 3rd day group (6.81 N/hr). The results of ANOVA table show that both the spawn density and the observation days significantly ($p=0$) affected the predatory efficiency of *Notonecta* spp.

Table 2: Predatory efficiency of *Notonecta* spp. on Rohu spawn and percent survivability of Rohu spawn

Spawn density (No. of spawn/ 80 L)	Predatory efficiency of *Notonecta* spp. on Rohu spawn						
	1d	**2d**	**3d**	**4d**	**5d**	**Predatory efficiency (N/hr)**	**% survivability**
10	2.25±0.34	2.22±0.11	2.19±0.39	2.16±0.35	2.17±0.24	2.19	85.4
15	3.19±0.06	3.17±0.03	2.13±0.17	3.10±0.88	2.08±0.95	3.14	81.23
20	4.7±0.50	4.68±0.46	3.55±0.56	3.44±0.16	4.2±0.77	4.52	75.4
25	5.94±0.68	5.86±.12	4.48±0.13	4.46±0.39	5.41±0.69	5.63	68.23
30	6.24±0.29	6.21±0.22	5.19±0.87	5.11±0.72	6.08±0.88	6.17	61.46
35	7.93±0.78	7.88±0.72	6.83±0.02	6.72±0.67	7.68±0.72	7.15	55.44
40	8.93±0.97	8.89±0.05	7.83±0.12	7.81±0.56	8.76±0.11	8.85	49.28
45	9.99±0.41	9.81±0.76	8.76±0.53	8.66±0.07	9.06±0.55	9.74	35.8
50	10.93±0.55	10.78±0.54	9.65±0.22	9.22±0.19	10.17±0.89	10.56	28.9
55	11.96±0.05	11.88±0.56	11.78±0.72	10.52±0.98	11.15±0.34	11.66	21.1
60	12.89±0.72	12.74±0.45	12.61±0.12	12.91±0.34	12.70±0.18	12.53	14.12
Mean	7.72	7.64	6.81	7.22	7.13		

Two-way Anova	C.D.	SE (m)	Df	F - value
Treatment	0.164	0.058	10	3,507.41
Days	0.111	0.039	4	22.377
Treatment × Days	N/A	0.131	40	1.121

(c) Predatory efficiency of *Notonecta* on Mrigal spawn and percent survivability of Mrigal spawn:
The mean predatory efficiency of *Notonecta* spp. on Mrigal spawn was observed significantly higher in the treatment's groups ($p<0.01$) as compared to the control groups (without *Notonecta*) during the experimental study. The minimum rate of predation was observed at lowest spawn density. With an increase in spawn density, the average predatory efficiency values of *Notonecta* increased from 3.72 N/hr to 13.61 N/hr. However, as the predatory efficiency increased, the percentage survivability of fish reduced from 85.4% to 14.12% (Table 3). The first day group (8.75 N/hr) had the highest predatory efficiency, followed by the second (8.42 N/hr), third (8.32 N/hr), fourth (8.29 N/hr), and fifth (8.01 N/hr) day groups. The ANOVA table results demonstrate that predatory efficiency is significantly ($p=0$) impacted by both spawn density and observation days.

Table 3: Predatory efficiency of *Notonecta* spp. on Mrigal spawn and percent survivability of Mrigal spawn

Spawn density (No. of spawn/ 80 L)	Predatory efficiency of *Notonecta* spp. on Mrigal spawn						
	1d	2d	3d	4d	5d	Predatory efficiency (N/hr)	% survivability
10	3.95±0.05	3.82±0.09	3.76±0.41	3.66±0.06	3.41±0.32	3.72	86.1
15	4.19±0.06	4.17±0.03	4.13±0.17	4.16±0.88	4.08±0.95	4.14	81.23
20	5.99±0.16	5.47±0.63	5.15±0.77	5.50±0.08	5.34±0.15	5.67	81.56
25	6.82±0.50	6.61±0.01	6.74±0.16	6.52±0.32	6.13±0.32	6.54	74.9
30	7.91±0.28	7.76±.78	7.68±0.62	7.51±0.03	8.21±0.34	7.62	67.78
35	8.94±0.02	7.88±0.67	8.79±0.07	7.31±0.04	8.18±0.43	8.61	61.76
40	9.73±0.18	9.67±0.02	9.44±0.11	9.38±0.07	9.18±0.09	9.48	55.78
45	10.98±0.17	9.90±0.22	9.88±0.65	10.72±0.12	10.32±0.91	10.76	49.87
50	11.91±0.12	11.81±0.03	10.69±0.83	10.99±0.34	11.32±0.05	11.66	34.9
55	12.89±0.15	12.79±0.03	12.74±0.71	11.79±0.61	12.07±0.12	12.49	28.2
60	12.99±0.02	12.79±0.01	13.67±0.34	13.96±0.08	13.93±0.01	13.61	21.56
Mean	8.75	8.42	8.32	8.29	8.01		

Two-way Anova	C.D.	SE (m)	Df	F - value
Treatment	0.142	0.051	10	5,052.602
Days	0.096	0.034	4	40.114
Treatment × Days	N/A	0.114	40	1.116

(d) Predatory efficiency of *Notonecta* spp. on Catla fry and percent survivability of Catla fry:

A considerably higher mean predatory efficiency of *Notonecta* spp. on Catla fry ($p<0.01$) as compared to the control groups (without *Notonecta*) was observed. The minimum rate of predation was observed at lowest fry density. With an increase in fry density, the average predatory efficiency values of *Notonecta* increased from 1.16 N/hr to 10.65 N/hr. The % survivability of fish fry was reduced from 87.9% to 15.67% with the increase in predatory efficiency (Table 4). However, the rate of predation on IMC fry was lower as compared to IMC spawn. The maximum predatory efficiency was reported on 1st day group (6.1 N/hr), followed by 3rd day group (6.07 N/hr), 2nd day group (6.01 N/hr), 4th day group (5.87 N/hr) and 5th day group (5.81 N/hr). The results of ANOVA table show that both the fry density and the observation days significantly ($p=0$) affected the predatory efficiency of *Notonecta.*

Table 4: Predatory efficiency of *Notonecta* spp. on Catla fry and percent survivability of Catla fry

Fry density (No. of fry / 80 L)	Predatory efficiency of *Notonecta* spp. on Catla fry						
	1d	2d	3d	4d	5d	Predatory efficiency (N/hr)	% survivability
10	1.71±0.14	1.59±0.04	1.36±0.05	1.23±0.13	1.11±0.21	1.16	87.98
15	2.16±0.11	2.11±0.12	2.1±0.04	3.0±0.05	1.88±0.78	1.86	82.88
20	3.27±0.68	3.23±0.12	3.19±0.05	3.13±0.11	2.91±0.34	2.56	76.19
25	4.18±0.56	4.12±0.19	3.96±0.23	3.84±0.56	3.71±0.12	3.56	70.32
30	5.06±0.11	5.0±0.21	4.93±0.11	4.72±0.12	4.61±0.88	4.65	62.86
35	5.29±0.05	5.18±0.32	6.13±0.14	4.88±0.34	6.71±0.78	5.77	56.68
40	6.37±0.31	6.21±0.23	6.11±0.67	5.64±0.21	5.51±0.34	6.56	51.23
45	8.2±0.18	7.88±0.87	7.76±0.34	8.54±0.21	7.32±0.63	7.7	36.12
50	9.25±0.04	10.23±0.15	9.11±0.21	8.78±0.45	9.52±0.56	8.52	29.16
55	10.52±0.13	10.39±0.56	11.28±0.21	9.87±0.12	9.72±0.21	9.74	22.3
60	11.08±0.04	11.04±0.22	10.85±0.12	11.12±0.15	11.18±0.13	10.65	15.67
Mean	6.1	6.01	6.07	5.87	5.81		

Two-way Anova	C.D.	SE (m)	Df	F - value
Treatment	0.131	0.047	10	4,787.216
Days	0.089	0.032	4	80.033
Treatment × Days	0.294	0.105	40	2.437

(e) Predatory efficiency of *Notonecta* spp. on Rohu fry and percent survivability of Rohu fry:

A considerably higher mean predatory efficiency of *Notonecta* spp. on Rohu fry ($p<0.01$) compared to the control groups (without *Notonecta*) was observed. At low fry densities, the lowest rate of predation was noted. Different observation day groups had equal initial mean predatory efficiency of *Notonecta*. When the fry density increased, the average predatory efficiency values increased from 1.67 N/hr to 11.39 N/hr. However, % survivability of fish fry was reduced from 88.1% to 17.4% with the increase in predatory efficiency (Table 5). The 1st day group (7.19 N/hr) had the highest predatory efficiency, followed by the 2nd (7.15 N/hr), 3rd (6.83 N/hr), 5th (6.55 N/hr), and 4th (6.49 N/hr) day groups.

The ANOVA table results demonstrate that predatory efficiency is significantly ($p=0$) impacted by both fry density and observation days.

Table 5: Predatory efficiency of *Notonecta* spp. on Rohu fry and percent survivability of Rohu fry

Fry density (No. of fry/ 80 L)	Predatory efficiency of *Notonecta spp.* on Rohu fry						
	1d	**2d**	**3d**	**4d**	**5d**	**Predatory efficiency (N/hr)**	**% survivability**
10	1.83±0.34	1.71±0.54	1.29±0.23	1.48±0.11	1.31±0.43	1.67	88.1
15	2.85±0.31	2.74±0.45	2.32±0.34	1.91±0.43	2.79±0.12	2.62	81.23
20	4.83±0.43	4.61±0.56	4.48±0.12	3.87±0.21	4.56±0.56	3.71	76.78
25	5.16±0.12	5.45±0.21	4.13±0.31	4.12±0.12	5.1±0.43	4.51	69.12
30	5.88±0.21	5.66±0.76	5.54±0.11	5.32±0.21	4.91±0.85	5.62	62.22
35	7.59±0.15	7.37±0.21	7.26±0.21	6.85±0.31	6.51±0.12	6.66	55.43
40	8.17±0.56	9.15±0.21	7.54±0.65	7.32±0.54	8.11±0.76	7.4	52.6
45	9.21±0.21	8.69±0.21	9.57±0.54	8.36±0.19	8.13±0.54	8.43	36.8
50	9.94±0.12	9.72±0.21	9.51±0.76	10.79±0.65	8.51±0.76	9.69	29.22
55	11.41±0.76	11.31±0.34	11.28±0.65	10.26±0.54	11.11±0.21	10.42	22.12
60	12.22±0.04	12.29±0.06	12.31±0.23	11.19±0.21	11.12±0.45	11.39	17.45
Mean	7.19	7.15	6.83	6.49	6.55		

Two way Anova	C.D.	SE (m)	Df	F - value
Treatment	0.141	0.050	10	4,287.37
Days	0.095	0.034	4	180.61
Treatment × Days	0.315	0.112	40	2.902

(f) Predatory efficiency of *Notonecta* spp. on Mrigal fry and percent survivability of Mrigal fry:

The mean predatory efficiency of *Notonecta* spp. on Mrigal fry was significantly higher in the observation day groups ($p<0.01$) as compared to the control groups (without *Notonecta*) during the experimental period. At low fry densities, the lowest rate of predation was noted. Different observation day groups had equal initial mean predatory efficiency of *Notonecta*. When the fry density increased, the average predatory efficiency values increased from 2.46 N/hr to 12.21 N/hr. However, % survivability of fish fry was reduced from 88.3 % to 16.32 % with the increase in predatory efficiency (Table 6). The maximum predatory efficiency was reported on 1st day group (7.83 N/hr), followed by 2nd day group (7.66 N/hr), 3rd day group (7.37 N/hr), 5th day group (7.22 N/hr) and 4th day group (7.15 N/hr). The results of ANOVA table show that both the fry density and the observation days significantly ($p=0$) affected the predatory efficiency of *Notonecta.*

Table 6: Predatory efficiency of *Notonecta* spp. on Mrigal fry and percent survivability of Mrigal fry

Fry density (No. of spawn/ 80 L)	Predatory efficiency of *Notonecta* on Mrigal fry						
	1d	2d	3d	4d	5d	Predatory efficiency (N/hr)	% survivability
10	2.81±0.04	2.74±0.89	2.29±0.66	1.66±0.23	1.78±0.31	2.46	88.3
15	3.77±0.14	3.67±0.43	3.52±0.67	2.79±0.05	3.68±0.32	3.11	83.12
20	4.81±0.34	4.77±0.54	4.21±0.98	3.92±0.09	4.82±0.17	4.42	77.15
25	6.21±0.12	6.16±0.01	5.71±0.31	5.55±0.31	5.39±0.08	5.42	70.66
30	6.49±0.09	6.36±0.56	6.23±0.04	6.12±0.23	5.85±0.88	6.52	63.87
35	8.83±0.02	8.69±0.12	7.65±0.31	7.52±0.13	8.21±0.11	7.65	57.34
40	9.19±0.23	8.85±0.11	8.61±0.12	9.11±0.09	7.89±0.12	8.43	51.72
45	9.81±0.41	9.72±0.12	9.68±0.11	10.26±0.14	8.84±0.13	9.42	37.3
50	10.81±0.41	10.57±0.05	10.32±0.19	9.59±0.01	10.91±0.21	10.41	30.12
55	11.56±0.12	11.21±0.12	11.49±0.04	10.26±0.08	11.11±0.05	11.52	23.6
60	12.33±0.09	12.19±0.22	11.68±0.61	12.43±0.65	11.31±0.21	12.21	16.32
Mean	7.83	7.66	7.37	7.15	7.22		

Two-way Anova	C.D.	SE (m)	Df	F - value
Treatment	0.140	0.050	10	3,995.194
Days	0.095	0.034	4	178.657
Treatment × Days	0.314	0.112	40	4.379

Discussion

Backswimmers mostly feed on spawn and fry stages of fish and tadpoles that are economically valuable (Kumar & Hwang, 2006). Specifically, aquatic bugs such as Notonectids and *Cybister* larvae, are known for predation of spawn and fry of many fish species. In this study, the mean values of predatory efficiency of *Notonecta* spp. for Catla spawn was increased from 1.38 N/hr to 11.51 N/hr with the increase in spawn density. The present investigation lines up with the findings of Berezina (1955) who reported that a large population of *N. glauca* has the capacity to destroy 2,500 -3,500 larvae of fish per day in ponds covering an area of around 0.01 hectare. The mean values of predatory efficiency of *Notonecta* for Rohu spawn increased from 2.19 N/hr to 12.53 N/hr with the increase in prey density. The maximum predatory efficiency was reported on 1st day group (7.72 N/hr), followed by 2nd day group (7.64 N/hr), 4th day group (7.22 N/hr), 5th day group (7.13 N/hr) and 3rd day group (6.81 N/hr). The present study correlates with the findings of Yurembam *et al*. (2016) stated that fish, especially in their larval phases such as spawn, fry, and fingerlings, have been reported to be harmed by aquatic predatory insects (*Notonecta*, *Ranatra, Cybister*, *Lethocerus*, *Nepa*, *Hydrometra* and *Belostoma*) found in various type of fish ponds, including nursery and stocking areas. Similarly, in the present study, with an increase in spawn density of Mrigal, the average predatory efficiency values of *Notonecta* increased from 3.72 N/hr to 13.61 N/hr. The first day group (8.19 N/hr) had the highest predatory efficiency, followed by the second (8.08 N/hr), third (7.97 N/hr), fourth (7.83 N/hr), and fifth (7.60 N/hr) day groups. A study conducted by Dahm (1972) revealed that on average, 2.6 fish larvae were destroyed by one adult *N. glauca* each day. Clark (1928) reported that *Notonecta undulata* are predators of a variety of small fish species in pond cultures, as well as larvae of different fish species inhabiting still freshwater environments. In a study conducted by Gorai & Chaudhari (1962) revealed that the fifth instar of *Anisops bouvieri (*Notonectid*)* is a common predator of fish larvae in India and has a highered capability to destroy fish spawn.

The average predatory efficiency values of *Notonecta* spp. for Catla fry increased from 1.16 N/hr to 10.65 N/hr with an increase in fry density. However, % survivability of fish was reduced from 85.4 % to 14.12 % with the increase in predatory efficiency. This study aligns with the findings of Hirvonen (1992) who reported increased frequency of cheliped losses (3.2 to 13.1 %) in young crayfish (*Astacus leptodactylus*) to avoid backswimmer predation. A high density of *Notonecta lutea* in the pond resulted in reduction survival rate (68 % to 32%) of crayfish. Singh *et al.* (2017) revealed the predatory behavior of *Notonecta* spp. in fish ponds. It was reported that the predatory bugs feed on various small animals including crustaceans, tadpoles, fish hatchlings, insects and their larvae. The average predatory efficiency values of *Notonecta* for Rohu fry increased from 1.67 N/hr to 11.39 N/hr with an increase in fry density. However, % survivability of fish was reduced from 85.4 % to

14.12 % with the increase in predatory efficiency. The 1st day group (7.19 N/hr) had the highest predatory efficiency, followed by the 2nd (7.15 N/hr), 3rd (6.83 N/hr), 5th (6.55 N/hr), and 4th (6.49 N/hr) day groups. In a study conducted by Sano *et al*. (2011) revealed that within a 24-hour period, one *Anisops bouvieri (*Notonectidae*)* preyed on an average of 2.8, 5.5, and 4.8 Silver barb, Indian carp, and Common carp larval fish respectively. Kashyap *et al*. (2013) stated that the highly predacious backswimmers are capable of destroying 10-13 mm fry of carps. Gonzalez and Leal (1995) reported that *Notonecta* spp. had higher predation rate on spawn and fry of fish, tadpoles and also showed predation on other insects. With the increase in fry density of Mrigal, the average predatory efficiency values of *Notonecta* spp. increased from 2.46 N/hr to 12.21 N/hr. However, % survivability of fish was reduced from 85.4 % to 14.12 % with the increase in predatory efficiency. The maximum predatory efficiency was reported on 1st day group (7.83 N/hr), followed by 2nd day group (7.66 N/hr), 3rd day group (7.37 N/hr), 5th day group (7.22 N/hr) and 4th day group (7.15 N/hr). Ganguly & Mitra (1961), revealed in a study that hemipterans *Notonecta* spp. were capable of destroying 16 fry per hour.

Conclusion

The data of present study proposes that the presence of these insects poses a serious threat to fish nurseries in India, where large-scale spawn to fry rearing of Indian major carps, including *Catla catla, Labeo rohita* and *Cirrhinus mrigala* occurs. The predatory efficiency of aquatic insects was found dependent on several factors, including: (i) prey density in the habitat*;* (ii) size and physiological state of prey; (iii) prey mobility; (iv) prey predator behavioural adaptation in the same habitat; and (v) the absence of predator detection mechanisms in prey species. This data can be utilized for enhanced survival and long-term management of Carps species.

References

1. Berchi, G. M., Copilaș-Ciocianu, D., Kment, P., & Mumladze, L. (2023). Water bugs (Heteroptera: Gerromorpha, Nepomorpha) of the Caucasus ecoregion. *The European Zoological Journal*, **90** (1), 167-192.
2. Berezina, N. A. (1955). On the feeding of some waterbugs-competitors and pest of fish fry. *Trudy Mosk. Technol. Inst. Rybn. Promyshl*, 7, 142-148.
3. Briers, R. A. (1999). *Metapopulation ecology of Notonecta in small ponds* (Doctoral dissertation, University of Sheffield), 1-154, pp.
4. Clark, L. B. (1928). Seasonal distribution and life history of *Notonecta undulata* in the Winnipeg region, Canada. *Ecology*, **9**(4), 383-403.
5. Cockrell, B. J. (1984). Effects of temperature and oxygenation on predator-prey overlap and prey choice of *Notonecta glauca*. *The Journal of Animal Ecology*, **53**(2), 519-532.
6. Dahm, E. (1972). On the biology of *Notonecta glauca* (Insecta, Hemiptera) with special reference to its damage to fisheries. *Internationale Revue der gesamten Hydrobiologie und Hydrographie*, **57**(3), 429-461.
7. Domingos, A. R., & Arcifa, M. S. (2016). Distribution and fluctuations of backswimmers (Notonectidae) in a tropical shallow lake and predation on microcrustaceans. *Brazilian Journal of Biology*, **77**(1), 108-117.
8. Ganguly, D. N., & Mitra, B. (1961). Observation on the fish fry destroying capacity of certain aquatic and the suggestion for their eradication. *Indian Agriculturist*, **5**(11), 184-188.
9. Giller, P. S., & McNeill, S. (1981). Predation strategies, resource partitioning and habitat selection in *Notonecta* (Hemiptera/Heteroptera). *The Journal of Animal Ecology*, **50**(3), 789-808.
10. González, A. V., & Leal, J. M. (1995). Predation potential of some aquatic insects (*Pantala, Coenagrion, Tropisternus, Notonecta* and *Sigara*) on common carp fry. *Journal of Applied Aquaculture*, **5**(1), 77-82.
11. Gorai, A. K., & Chaudhuri, D. N. (1962). Food and feeding habits of *Anisops bouvieri Kirk*. (Heteroptera: Notonectidae). *J. Asiat. Soc*, **4**(3-4), 135-139.
12. Griffith, T. B., & Gillett-Kaufman, J. L. (2021). Common Backswimmer *Notonecta glauca* (Linnaeus 1758) (Hemiptera: Notonectidae): **2021**(2), 3-3.
13. Hirvonen, H. (1992). Effects of backswimmer (*Notonecta*) predation on crayfish (*Pacifastacus*) young: Autotomy and behavioural responses. *Annales Zoologici Fennici*, **29**(4), 261–271.
14. Kashyap, A., Gupta, M., & Serajuddin, M. (2013). Predatory insects of various fish ponds detrimental to polyculture: a survey. *Research Journal of Life Sciences*, **1**(2), 21-24.
15. Kumar, R., & Hwang, J. S. (2006). Larvicidal efficiency of aquatic predators: a perspective for mosquito biocontrol. *Zoological Studies-Taipei-*, **45**(4), 447 -466.
16. Land, M. F. (1980) Eye movements and the mechanism of vertical steering in euphausiid crustacea. *J, Comp., Physiol.*, **137**(9), 255–265.

17. Martín, J., & López, P. (2004). Balancing predation risk, social interference, and foraging opportunities in backswimmers, *Notonecta maculata*. *Acta Ethologica*, **6***(2)*, 59-63.
18. Reynaldi, S., Meiser, M., & Liess, M. (2011). Effects of the pyrethroid fenvalerate on the alarm response and on the vulnerability of the mosquito larva *Culex pipiens molestus* to the predator *Notonecta glauca*. *Aquatic Toxicology*, **104**(1-2), 56-60.
19. Sano, K., Miyoshi, K., Ishikawa, S., Liepvisay, N., & Kurokura, H. (2011). Impact of predation by water insects on fish seed production in Lao PDR. *Japan Agricultural Research Quarterly: JARQ*, **45**(4), 461-465.
20. Šigutová, H., Šigut, M., Dolný, A., & Harabiš, F. (2022). Individual variability in habitat selection by aquatic insects is driven by taxonomy rather than specialisation. *Scientific Reports*, **12**(1), 20735.
21. Singh, J., Shoeb, M., Chandra, H., Gupta, Y. K., Singh, S., & Sharma, H. N. (2017). Description of Digestive Tract of *Notonecta glauca Linn*., the Indian Backswimmer. *Journal of Advanced Laboratory Research in Biology*, **8**(1), 18-24.
22. Tripathi, S. D., & Sharaf, R. K. (1975). Predatory role of weed fishes vis-a-vis aquatic insects, tadpoles and froglets. *JNKVV Res J Jawaharlal Nehru Krishi Vishwa Vidylaya*. **8(2)**, 123- 127.
23. Weterings, R., Vetter, K. C., & Umponstira, C. (2014). Factors influencing the predation rates of *Anisops breddini* (Hemiptera: Notonectidae) feeding on mosquito larvae. *Journal of Entomological and Acarological Research*, ***46***(1), 107-111.
24. Yurembam Motilan, Y. M., Radhakrishore, R., Konsam Nishikanta, K. N., Khaidem Alka, K. A., Gojendro, O., & Ruhini, T. (2016). Predatory aquatic insects of nursery ponds of Manipur. *J. Exp. Zool. India*, **19**(2), 799-803.