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# Effect of Change in Physical Parameters in the Paddling Response of the Common Backswimmer (*Notonecta glauca*)

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

This study investigates the impact of varying environmental factors, specifically temperature, pH, and white light intensity, on the paddling response of the common backswimmer, *Notonecta glauca* Linnaeus 1758 (Hemiptera: Notonectidae). The normal paddling rate was established at approximately 31.6 flaps per minute (FPM) under controlled conditions of 30°C, pH 6.8, and 50% sunlight exposure. When exposed to increased pH levels, the paddling rate exhibited a significant increase, rising by nearly 75% compared to the normal rate. Conversely, a decrease in pH led to an even greater enhancement in paddling activity, with a rise of approximately 90%. A notable

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response was observed under increased temperature, where the paddling rate surged by more than 2.6 times than expected, indicating a strong sensitivity to thermal changes. The most reduction in paddling activity occurred under low light intensity, with the rate plummeting to roughly 37% of the normal value. The findings underscore the susceptibility of *N. glauca* to variations in these key environmental parameters, particularly highlighting its heightened response to temperature fluctuations and low light conditions. The species of interest is observed as *ecological sentinels* and understanding its optimum limit of tolerance over fundamental physical parameters enables us to estimate the effect of climate change, environmental modifications and habitat alterations over the course of time.

*Keywords: Notonecta glauca; bioindicator; freshwater ecosystems; thermal sensitivity; aquatic ecology; environmental monitoring; ecological sentinels.*

## 1. INTRODUCTION

The study of aquatic Hemiptera, particularly the family Notonectidae, is of significant interest due to their roles as bio-indicators of water quality, their ecological importance as keystone predators, and their relevance in understanding zoogeographic relationships (Bueno, 1905; Williams & Feltmate, 1992). Notonectidae, commonly known as backswimmers, are a cosmopolitan family of aquatic insects recognized for their distinctive behaviour of swimming upside down (Cheng, 1976; Ferzoco, 2019). These insects are abundant in still freshwater systems, particularly in regions such as the southern part of Kerala, India, where they are key components of the aquatic ecosystem (Anderson & Smith, 2000; Bal & Kapoor, 2021). Notonecta species are notable for their streamlined, deep-bodied appearance, which ranges in colour from green to brown or yellowish (Hutchinson, 1967). Their body length varies from 0.5 to 1.6 cm, and they are equipped with hind legs fringed with hair, adapted for swimming (Cheng, 1976). Unlike the water boatmen of the family Corixidae, backswimmers are predators that utilize their piercing and sucking mouthparts to capture and consume prey, including other aquatic insects, tadpoles, and small fish (Culler & Lamp, 2009). The predatory nature of backswimmers, coupled with their ability to inflict painful bites on humans, underscores their role as dominant predators in their habitats (Usinger, 1956).

The ecological significance of Notonecta species extends beyond their predatory behaviour. As top carnivores in many microhabitats, they play a crucial role in shaping the structure and abundance of zooplankton populations in freshwater environments (Herwig and Schindler, 1996). Their predation directly influences zooplankton community structure, impacting both prey size and predator-prey dynamics (McPeek, 1990; Blaustein & Kotler, 1993). Backswimmers have been observed to feed on a wide variety of aquatic organisms, including rotifers, crustaceans, mosquito larvae, and even terrestrial organisms trapped on the water surface, such as bees and ants (Culler & Lamp, 2009). This broad diet allows them to thrive in diverse environments, making them a critical component of lentic ecosystems (Coll & Stiling, 1996).

The backswimmer's ability to survive and thrive in both aquatic and terrestrial habitats is a testament to their adaptability (Corbet, 1962; Sundar & Dharan, 2017). They are commonly found in man-made water sources like pools and fountains, as well as in natural, slow-moving waters such as ponds, lakes, and streams (Dudgeon et al. 2006). Their preference for environments with lush vegetation provides them with ample opportunities to hide and hunt for prey (Essenberg, 1915; Ellis, 1969). Notonecta species are also capable of diving to significant depths, demonstrating their versatility in exploiting different parts of their habitat. One of the key adaptations of Notonecta species is their ability to breathe air rather than relying solely on dissolved oxygen in water. Their bodies are covered in hair-like structures called setae and microtrichia, which trap air and create a film that allows the insects to absorb oxygen while underwater (Ditsche et al. 2011). This adaptation not only enables them to stay submerged for extended periods but also contributes to their resilience in various environmental conditions. The ability to maintain an air film for up to 130 days for its survival highlights their efficiency in utilizing available resources to survive in challenging environments (Miller, 1964).

The reproductive behaviour of backswimmers in lentic water habitats further illustrates their adaptability (Forbes, 1989; Hayashi, 2023). During the mating season, males produce a unique sound by rubbing their front legs against their rostrum, a behaviour known as stridulation, to attract females (Aiken, 1985). Females then lay eggs on aquatic vegetation or other substrates, with the eggs hatching into nymphs that undergo several growth stages, known as instars, before reaching adulthood (Chapman, 1998). The life cycle of Notonecta species, from egg to adult, is completed in approximately six months, allowing for the production of two generations per year (Borror et al., 1989). This rapid life cycle contributes to their ability to maintain stable populations in their habitats (Hocking, 1952). The ability of Notonecta species to perceive their environment through their highly specialized compound eyes is another remarkable aspect of their biology. These insects possess a unique visual system that allows them to see in both day and night conditions (Schwind, 1978; Schoenemann et al. 2017). The eyes of Notonecta species are adapted for both aquatic and aerial environments, with a corneal structure that helps them create sharp images (Warrant & Dacke, 2011). The presence of large, green-sensitive peripheral photoreceptors enables them to detect prey and navigate in dim light conditions, while smaller photoreceptors allow them to function in bright light and during flight. This visual adaptation is crucial for their predatory lifestyle and ability to disperse to new habitats (Kiyoshi, 1984; Land & Nilsson, 2012).

The ecological importance of Notonecta species extends to their role as bioindicators of water quality. Their presence and abundance in freshwater systems can provide valuable insights into the health of aquatic ecosystems. Given their sensitivity to changes in environmental conditions, studying the response of Notonecta species to variations in temperature, pH, and light intensity can offer important information on the impacts of environmental stressors on aquatic communities (Herwig and Schindler, 1996; Urban et al., 2016). The ability of Notonecta species to switch between aquatic and terrestrial environments further underscores their potential as model organisms for studying the effects of environmental changes on aquatic invertebrates.

In this study, the focus is on evaluating the paddling response of the common backswimmer, *Notonecta glauca*, to changes in temperature, pH, and white light intensity. This research aims to provide a formal understanding of how these physical or abiotic parameters influence the behavior of *N. glauca*, particularly in the context of their paddling activity. By measuring the average paddling in unit time under normal conditions and then exposing the insects to altered physical conditions, this study seeks to elucidate the effects of environmental changes on the behaviour of *N. glauca*. Understanding the response of this species to changes in critical abiotic components is not only relevant for ecological research but also for the management of aquatic ecosystems. Given the increasing concern over the impacts of climate change and human activities on freshwater habitats, this study offers valuable insights into the resilience and adaptability of key aquatic predators (Poff et al., 2002). The findings of this research could have implications for the conservation and management of freshwater ecosystems, particularly in tropical regions where Notonecta species are prevalent.

**Fig. 1. Up-side down floating *Notonecta glauca***

## 2. MATERIALS AND METHODS

Collection and maintenance of back swimmers: *Notonecta sp* (60 Nos.), were collected from artificial ponds located in front of Library and the one inside the botanical garden green house, Mar Ivanios College, Trivandrum (8.5241° N, 76.9366° E). Back swimmers were initially spotted in the stagnant fresh water and then they were collected by using a nylon strainer. At most care was given for them not to be damaged or escaped during collection and were transferred to plastic buckets (25 l) containing 10 l fresh water. Since Backswimmers can jump and can survive in the terrestrial environment, the collection buckets were kept closed with a plastic net. Through-out the collection, the buckets were kept away from direct sun-light. *Ad-libitum* supply of mosquito larvae was provided to the experimental animals, three times a day as in every 2 hours from time hours 9.00 to 15.00. Any mortality observed during maintenance was removed and we change the water in every 3 days.

General methods adopted in experiments: All the experiments were conducted within a period, 11.30 am to 11.55 am and 12.00 pm to 12.25 pm in multiple days. For every experiment, 5 minutes' observations (3 nos.) were taken with 5 minutes' gap in between each bout. An observer observed two systems that are randomly assigned to them in order to avoid individual bias over a particular system throughout the experiments. An observer counts the number of paddling made by a randomly fixed individual of *Notonecta glauca* out of the given five numbers in an experimental system. In any case, if the selected individual jumps out of the water surface, the observer has the freedom to again randomly pick any other individual out of the four remaining. In any case if all the five *Notonecta glauca* jumped out of the system the particular observation will be repeated once again. The paddling rate per minute was calculated by counting the total number of paddles in five minutes and dividing it by total number of minutes (t); (*here t = 5*).

For all the experiments in the project we randomly selected our system to be observed through lot that assures an equal chance to get a system for every observer without any human error. By employing multiple observers, the experimental time was significantly reduced, that again lowers the chance of any temporal physical error over experimental system. The Division of labour chart generated is given in Table 1.

Estimation of the normal rate of paddling: *Notonecta glauca* (5 nos.) were collected randomly from the reserve and placed in a 500 ml conical flask (Make: Borosil) with 250 ml of tap water (pH ˜ 6.8) sourcing from *Mar Ivanios College* campus pond. 10 replications of such system (System-1 to 10) where kept undisturbed for half an hour in a well-lit place with a good amount of indirect sunlight, which is the preferred condition for *N. glauca*. As described in Table 1; candidates start to observe for the normal rate of paddling. Minimum disturbance from the observer side was assured throughout the experiment.

Estimation of the rate of paddling to change in pH: *Notonecta glauca* (5 nos.) were collected randomly from the reserve and placed in a 500 ml conical flask with 250 ml tap water. Out of the taken 10 systems, we randomly assigned six systems as 'test' and four systems as 'control' - so that an equal share (2 controls and 3 tests each) for the high and low pH systems were assured from both test and control. pH of tap water was observed to be 6.8 and we use 0.1 normal HCl to lower the pH of the medium at 4.8 in the low pH test systems. 0.2 normal NaOH was employed to raise the pH of the medium at 8.8. After proper labelling, the system where kept undisturbed for half an hour in a well-lit place with a good amount of indirect sunlight. As described in Table 1; candidates start to observe for the rate of paddling in both test and control. Minimum disturbance from the observer side was assured throughout the experiment. The experiment was conducted in the first time slot 11.30 am to 11.55 am.

Estimation of the rate of paddling to change in temperature: *Notonecta glauca* (5 nos.) were collected randomly from the reserve and placed in a 500 ml conical flask with 250 ml normal tap water. Out of the taken 10 systems, we randomly assigned 6 systems as 'test' and 4 systems as 'control'- so that an equal share (2 controls and 3 tests each) for the high and low temperature systems were assured from both test and control. Temperature of the tap water at room conditions was observed to be 30º C. After proper labelling, the high temperature experimental test systems (3 nos.) were placed in a water bath (Make: Beston) maintained at a temperature of 35ºC. A thermometer was also placed in one of the system for temperature scaling. The set-up was kept undisturbed for half an hour in a well-lit

**Table 1. Division of labour to candidates selected for the execution of project**

| **Observer's name abbreviated:** | | **SR** | **STS** | **SSP** | **SSS** | **SNGK** |
|---|---|---|---|---|---|---|
| **Stable state experiment** | | System-9 | System-8 | System-10 | System-2 | System-7 |
| | | System-1 | System-3 | System-5 | System-6 | System-4 |
| Experiment-1 | High | Control-1 | Control-3 | Test-3 | Test-6 | Test-2 |
| (pH) | Low | Control-2 | Test-5 | Test-4 | Test-1 | Control-4 |
| Experiment-2 | High | Test-2 | Control-1 | Control-2 | Test-1 | Test-4 |
| (Temperature) | Low | Test-3 | Control-4 | Test-5 | Test-6 | Control-3 |
| Experiment-3 | Normal | *Results taken from the stable state experiment* | | | | |
| (Light intensity) | Low | Test-1 | Test-8 | Test-9 | Test-7 | Test-4 |
| | | Test-6 | Test-2 | Test-5 | Test-10 | Test-3 |

place with a good amount of indirect sunlight. Mean time we had kept the low temperature experimental test systems (3 nos.) and control systems separately for observation in a well-lit place with a good amount of indirect sunlight. From the low temperature experimental test systems, we had removed 30 ml of water (by using a pipet) in order to keep the volume of water constant while adding cold water to lower the temperature of the system to 28ºC. The high temperature experimental test systems and half of the control systems were scrutinized in a time period 11.30 am to 11.55 am followed by the observation of the low temperature experimental test systems and the other half of the control in a time period 12.00 pm to 12.25 pm.

Estimation of the rate of paddling to change in intensity of light: *Notonecta glauca* (5 nos.) were collected randomly from the reserve and placed in a 500 ml conical flask with 250 ml tap water. 10 systems were considered as test by covering the system with black paper. This assures the intensity of light as 35,000 lux. while the control is receiving 70,000 lux. After proper covering and labelling, the system where kept undisturbed for half an hour. Candidates start to observe for the rate of paddling through the mouth of the conical flask as described in Table 1.

## 3. RESULTS AND DISCUSSION

Estimation of the normal rate of paddling by *Notonecta glauca* indicate, the average flaps per minute under normal conditions of temperature at 30º C, pH at 6.8 and intermediate sun-light exposure of 35,000 lux. (50% shade) was estimated to be 31.6 ± 15.42 flaps per minute (FPM). On the observation of the rate of paddling by *N. glauca* to change in pH. The average flaps per minute under increased pH is observed to be 55 ± 6.24 FPM. The average flaps per minute under decreased pH is observed to be 60 ± 13 FPM. The average flaps per minute under increased temperature to *N. glauca* yield 113 ± 62 FPM. Estimation study on the rate of paddling by *N. glauca* to change in intensity of light gives 11.6 ± 6.48 FPM under low intensity of light.

General inference from the current study are defined in Table 2; from the study it is clear that the rate of flaps made by the *Notonecta glauca* vary in relation to the fundamental physical parameters such as pH, temperature and intensity of light. The study observes a very clear response in the flapping activity when light is reduced in the system. A change in temperature (an increase of 5º C from normal) brought about a significant response in the flapping activity of back swimmers to a tune of 3.6 times. Flapping response over change in pH observes that backswimmers are not comfortable to both acids as well as alkali influx; but in comparison they are observed to be more tolerant to alkaline influx to their system.

**Table 2. General inference from the study on the effect of change in temperature, pH and light intensity in the paddling response of *Notonecta glauca***

| | **High (pH: 8.8; Temp: 35℃ Light: 70000 Lux)** | **Intermediate/ Control (pH: 6.8; Temp: 30℃; Light: 70000 Lux)** | **Low (pH: 4.8; Temp: 28℃; Light: 35000 Lux)** |
|---|---|---|---|
| **pH** | 55± 6.24 | 31.6± 15.42 | 60± 13 |
| **Temperature** | 113 ± 62 | 31.6± 15.42 | 35± 6.5 |
| **Light** | *Not executed* | 31.6± 15.42 | 11.6± 6.48 |

*All the values indicate Number of Flaps Per Minute (FPM) along with respective Standard Deviation (SD) values*

Under increased temperature, escalated paddling activity, aligning with previous observations that temperature influences metabolic processes in aquatic insects. Changes in pH revealed a marked response, with backswimmers exhibiting higher paddling rates under acidic conditions compared to alkaline influx, indicating stress sensitivity to pH fluctuations. Notably, reduced light intensity caused a sharp decline in paddling activity, underscoring their reliance on visual cues for movement and predation (Schwind, 1978). Singh and Shoeb (2024) had worked on the effect of temperature, dissolved oxygen, and prey availability for *N. glauca* and observed that they are the most significant factors influencing the species' behaviour and distribution. The current study also corroborates with the general observation by Wetzel, R.G. (2001) as the abiotic factor optimums are foundational for the existence of *ecological sentinels* like *N. glauca.*

The findings highlight the role of *Notonecta glauca* as ecological sentinels, with their paddling rates offering valuable insights into environmental changes. Understanding their tolerance limits to temperature, pH, and light intensity provides a baseline to assess the impacts of climate change, habitat modifications, and anthropogenic disturbances. The clear sensitivity of paddling activity, particularly to temperature increases and light reductions, underscores their potential as bioindicators. These responses not only reflect immediate environmental stress but also offer a predictive framework for evaluating the long-term effects of changing ecosystems, aiding in conservation and adaptive management strategies.

## 4. CONCLUSION

This study demonstrates that the paddling rate of *Notonecta glauca* is significantly influenced by changes in environmental factors such as pH, temperature, and light intensity. The results show a marked increase in paddling activity with elevated pH and temperature, highlighting the species' sensitivity to thermal changes. In contrast, reduced light intensity led to a dramatic decline in paddling rate, emphasizing the importance of light exposure in regulating behaviour. The study also reveals that *N. glauca* is more tolerant to alkaline pH conditions compared to acidic ones. These findings underscore the potential of *N. glauca* as a bioindicator species for monitoring environmental changes and stressors, providing valuable insights into the impact of climate change and habitat alterations on aquatic organisms. The study not only enhances our understanding of *N. glauca*'s ecological role but also opens avenues for using this species as an indicator of environmental health, bridging the gap between ecological research and public health. The study calls for a re-evaluation of how we perceive and manage freshwater ecosystems, advocating for the conservation of such neustone species that are crucial to the ecological integrity and resilience of these habitats.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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