



Research Paper

Behavioural Responses of the Freshwater Bivalve *Lamellidens marginalis* to Chronic Exposure to Lambda-Cyhalothrin, Imidacloprid and Their Binary Mixture

Poonam Ahire and Anil Kurhe

Department of Zoology, P. V. P. College of Arts, Science and Commerce, Loni (kd)- 413713, Tal -Rahata, Dist. Ahilyanagar (Maharashtra) India

How to Cite

Ahire, P. & Kurhe, A. (2026) Behavioural Responses of the Freshwater Bivalve *Lamellidens marginalis* to Chronic Exposure to Lambda-Cyhalothrin, Imidacloprid and Their Binary Mixture. *Journal of Fisheries and Zoological Sciences*, 1(4), 31-36. <https://doi.org/10.65385/JFZS0028>

ISSN: 3108-1991 (online)

Article History

Received 12 August 2026

Accepted 11 October 2026

First Online 15 October 2026

Corresponding Author

E-mail: anil.kurhe@gmail.com

Keywords

Behavioural responses
Lamellidens marginalis
Lambda-cyhalothrin
Imidacloprid
Mucus secretion

Abstract

The presence of pesticides in freshwater habitat affects nontarget aquatic organisms. Freshwater bivalves are useful indicators of the impact of pesticides due to their continuous exposure to surrounding water. The current study aimed to investigate *Lamellidens marginalis* behavioural responses after LC (lambda-cyhalothrin), IMI (imidacloprid), and the binary mixture of LC+IMI chronic toxicity (21 d). There were four treatment groups (control, LC, IMI, and LC+IMI) (n=4) and observed for mucus secretion, valve gaping and closing, extension and withdrawal of the foot, and siphoning activity at 2, 4, 6, 12, and 24 h on Day 0, Day 1, and Day 3 (24 h). Observation was conducted at every day from Day 4 to Day 21. *Lamellidens marginalis* control mussels maintained normal behavioural activity throughout the study period. A significant deviation in normal behaviour and moderate mucus secretion was observed in LC, IMI treatments. The mucus secretion score was 0 for control treatment, 2 for both LC and IMI treated groups, and 3 for LC+IMI treatment. Moreover, LC+IMI resulted in long/complete closure of valves, strongly reduced foot movement, and impaired siphon function. In general, behavioural responses can be used as a reliable biomarker in *L. marginalis* exposed to LC and IMI.

1. Introduction

Freshwater ecosystems are exposed to contaminants such as agricultural runoff, domestic discharge and other human activities. Pesticides, in particular can enter freshwater environments after agricultural use. Even at low concentrations, pesticides can affect feeding, respiration, filtration, movement and other normal activities of aquatic organisms that are not their intended targets (Saha & Dutta, 2024). This is a particular concern in freshwater areas surrounded by agricultural land. A recent study of the Darna River reported changes in its physicochemical characteristics and pointed to the need for regular ecological monitoring (Ahire & Khure, 2026). The river is also included in Maharashtra's polluted-river monitoring framework (MPCB, 2025).

Freshwater bivalves are useful in ecotoxicological studies because they generally remain in one place and filter large amounts of surrounding water (Verheyken & Aldridge, 2023). Studies have also highlighted their use as biological sensors and early-warning organisms for monitoring water quality (Verheyken & Aldridge, 2023).

Behaviour is another important way in which organisms respond to environmental stress. Changes in behaviour can affect feeding, movement, filtration and survival. Behavioural observations also have the advantage of being recorded repeatedly without harming or destroying the organism. Valve movement, filtration and locomotion are thus widely used in aquatic ecotoxicology (Hartmann et al., 2016). Recent studies have shown that exposure to chemicals can alter mussel movement; continuous behavioural monitoring can help detect toxic effects (Berthelot et al., 2025). High-frequency video analysis has further shown that behaviour measurements can provide valuable information beyond conventional valvometry in bivalves (Escobar-Calderón et al., 2022). Similar changes have also been observed in other aquatic invertebrates exposed to pesticides (Egan et al., 2023). *L. marginalis* is an important freshwater bivalve found in the Indian subcontinent and has been used in several ecotoxicological studies. Indian studies have shown that this species is sensitive to various pesticides and other contaminants. Imidacloprid exposure, in particular has been linked with histopathological damage and lipid peroxidation in *L. marginalis* (Ahire & Dethe, 2023).

Earlier studies on *L. marginalis* reported changes in shell closure, mucus secretion, foot activity and siphoning after pesticide exposure (Pandit and Mundhe, 2013; Raj and Suganthi, 2015). Lambda-cyhalothrin is a synthetic pyrethroid that mainly affects voltage-gated sodium channels. Imidacloprid is a neonicotinoid that mainly acts on nicotinic acetylcholine receptors (Soderlund, 2012; Matsuda et al., 2001). Since these pesticides act in different ways, their combined presence in aquatic environments is important to consider. Contaminants, in particular, often combine to form mixtures in aquatic environments, and individual pesticides are rarely present. The effects of such mixtures may also differ from those caused by individual pesticides (Guille et al., 2025). Recent experimental work has reported stronger effects following combined exposure to lambda-cyhalothrin and imidacloprid in aquatic organisms (Alvim et al., 2025). Behavioural changes are useful for assessing stress in bivalves as valve movement, siphoning and foot activity are part of their normal activities. Mucus secretion may also change when the animals are exposed to chemical stress. However, limited information is available on the long-term behavioural effects of lambda-cyhalothrin and imidacloprid on *L. marginalis*, in particular when both pesticides are present together. Therefore, the present study examined the behavioural responses of *L. marginalis* during 21-day chronic exposure to lambda-cyhalothrin, imidacloprid and their binary mixture. The study focused on mucus secretion, valve movement, foot activity and siphoning. It also compared the responses to individual pesticides with those observed under combined exposure and assessed their use as indicators of pesticide-related stress.

2. Materials and Methods

2.1 Study Area and Animal Collection

Specimens of *L. marginalis* (Lamarck, 1819) were collected from the Darna River at Chehadi, Nashik District, Maharashtra, India. The collection site was located at approximately 19°55'54.02" N and 73°55'30.42" E. The river flows through an agriculturally influenced region (Ahire & Khure, 2026). Adult bivalves of similar size, with shell lengths of 55–65 mm, were selected. Only animals with a normal appearance were used. The specimens were transported to the laboratory in river water.

2.2.2 Acclimatization and Laboratory Maintenance

The animals were acclimatized for 3–4 days in plastic troughs containing dechlorinated tap water. The temperature was maintained at 24 ± 2 °C with a 12:12 h light: dark cycle. Crushed *Spirulina* was provided as food. Water was replaced every 24 h. Only healthy animals showing normal valve movement, siphoning and foot activity were used for the experiment.

2.3 Test Chemicals

Commercial formulations of lambda-cyhalothrin (5% EC) and imidacloprid (30.5% m/m SC) were used. Stock solutions were prepared in dechlorinated water. These were then diluted to prepare the required working solutions. For the binary-mixture treatment, lambda-cyhalothrin and imidacloprid were combined in a fixed ratio of 45.05% and 54.95%, respectively, as established in the 21-day chronic toxicity experiment. The concentrations used for behavioural observations were selected from the 21-day chronic toxicity experiment. This study focused on behavioural responses and did not establish an independent behavioural concentration-response relationship.

2.4 Experimental Design

After acclimatization, the animals were divided into four groups: Control, lambda-cyhalothrin (LC), imidacloprid (IMI) and binary mixture of LC + IMI. The exposure continued for 21 days. Test solutions were renewed every 24 h. Control animals were maintained in pesticide-free dechlorinated water.

2.5 Behavioural Observation Schedule

The behavioural responses of *L. marginalis* were recorded throughout the 21-day chronic exposure experiment. Observations were made at 2, 4, 6, 12 and 24 h on Day 0. Further observations were made at 24 h on Days 1 and 3. From Days 4–21, observations were made daily at 24 h. The behavioural endpoints included mucus secretion, valve opening and closing, foot extension and retraction, and siphoning activity. Responses were recorded through direct observations and videographic recordings. The responses were then compared among the control, individual pesticide and binary-mixture treatments.

2.5.1 Mucus Secretion

Mucus secretion was scored on a four-point scale: 0 = no visible mucus, 1 = slight mucus, 2 = moderate mucus and 3 = excessive mucus. Mucus was observed around the shell margin and exposed soft tissues. The changes in mucus production were recorded during the observation period and compared among the control and treatment groups.

2.5.2 Valve Opening and Closing

Valve behaviour was assessed by observing normal opening and closing. Prolonged closure, intermittent opening, reduced opening and complete shell closure were recorded. Valve movement is an important behavioural endpoint in bivalve biomonitoring (Vereycken & Aldridge, 2023). Changes in the normal valve movement pattern were recorded throughout the exposure period and compared among the treatment groups.

2.5.3 Foot Extension and Retraction

Foot activity was assessed by observing extension and retraction of the muscular foot. Reduced activity, reduced extension frequency, strongly reduced activity or absence of normal movement was recorded.

2.5.4 Siphoning Activity

Siphoning was assessed by observing siphon extension, withdrawal and continuity of normal activity. Reduced, altered or interrupted siphoning was recorded in exposed animals.

2.6 Data Interpretation

Behavioural responses were assessed descriptively. No statistical significance was assigned as replicate-level numerical data were unavailable.

3. Results

3.1 General Behavioural Response

Control animals showed normal behaviour throughout the 21-day exposure period. They showed normal valve opening and closing, normal siphoning, and normal foot extension and retraction. There was no any excessive mucus secretion observed. Treated animal with lambda-cyhalothrin and imidacloprid showed noticeable changes in their normal behaviour. These included increased mucus secretion, altered valve movement, reduced foot activity, and reduced siphoning. The binary mixture produced the strongest overall behavioural changes. Mixture-exposed animals showed excessive mucus secretion, prolonged or complete valve closure, strongly reduced foot activity, and interrupted siphoning. Overall, the qualitative pattern was: Control < Individual pesticide treatments < Binary mixture. This pattern indicates a treatment-associated behavioural gradient. It should not be considered a statistically established dose-response relationship.

3.2 Mucus Secretion

Mucus secretion showed a clear difference between the control and pesticide-treated groups. Control animals showed no visible increase in mucus secretion and were assigned a mucus score of 0. In the lambda-cyhalothrin-treated group, moderate mucus production was observed, with a score of 2. A similar response was recorded in the imidacloprid-treated group, which also received a score of 2. In both individual pesticide treatments, mucus production was more noticeable than in the control animals. The strongest response was observed in the binary mixture group. Animals exposed to the mixture showed excessive mucus production and received the highest score of 3. Thus, the mucus response followed the pattern Control < lambda-cyhalothrin = imidacloprid < binary mixture. The increased mucus secretion in the treated groups was observed alongside other visible behavioural

changes during the exposure period. The highest mucus score recorded in the mixture group indicates that combined exposure produced a more pronounced mucus response than either pesticide alone (Table 1; Figure 1).

Table 1: Mucus secretion responses of *L. marginalis* following chronic pesticide exposure

Treatment	Mucus score	Response
Control	0	No visible mucus
Lambda-cyhalothrin	2	Moderate mucus production
Imidacloprid	2	Moderate mucus production
Binary mixture	3	Excessive mucus production

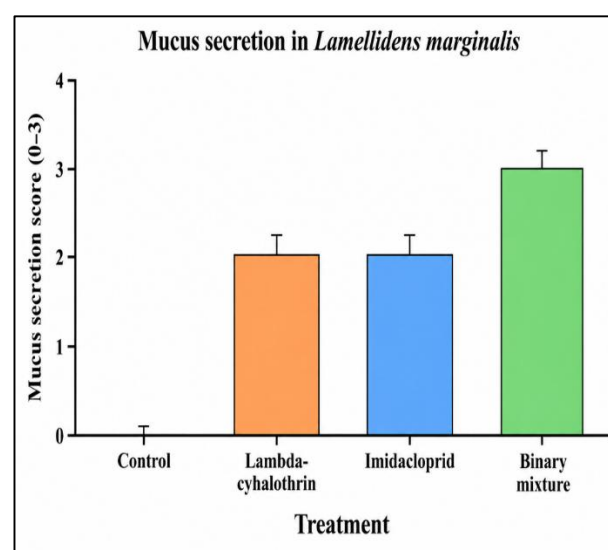


Figure 1: Mucus secretion scores of *L. marginalis* following 21-day chronic exposure to lambda-cyhalothrin, imidacloprid and their binary mixture

3.3 Valve Opening and Closing

Control animals showed normal valve opening and closing throughout the study. Lambda-cyhalothrin-treated animals showed prolonged valve closure followed by intermittent opening with reduced amplitude. Imidacloprid-treated animals showed irregular valve movement, with changes in the normal opening and closing pattern. The strongest response was observed in the binary mixture group, where prolonged and complete shell closure was frequently recorded. (Table 2).

Table 2: Valve opening and closing responses of *L. marginalis* following chronic pesticide exposure

Treatment	Observed valve response
Control	Normal opening and closing
Lambda-cyhalothrin	Prolonged closure and intermittent opening
Imidacloprid	Irregular valve movement
Binary mixture	Prolonged and complete closure

3.4 Foot Extension and Retraction

Control animals showed normal foot extension and retraction. Lambda-cyhalothrin exposure caused reduced foot activity, while imidacloprid exposure reduced the frequency of foot extension. The mixture-treated animals showed a strong reduction in foot activity (Table 3).

Table 3: Foot extension and retraction responses of *L. marginalis* following chronic pesticide exposure

Treatment	Foot response
Control	Normal extension and retraction
Lambda-cyhalothrin	Reduced activity
Imidacloprid	Reduced frequency of extension
Binary mixture	Strongly reduced activity

3.5 Siphoning Activity

Control animals maintained active and continuous siphoning throughout the observation period. Animal which treated with Lambda-cyhalothrin-treated showed reduced siphoning activity as compared with the control group while Imidacloprid treated animals also showed reduce siphoning activity and caused changes in its normal pattern? The strong noticeable changes were observed in the binary mixture group, where siphoning became interrupted. Overall, the treated groups showed a clear reduction in normal siphoning activity, with the most pronounced change recorded under combined exposure (Table 4).

Table 4: Siphoning responses of *L. marginalis* following chronic pesticide exposure

Treatment	Siphoning activity
Control	Active
Lambda-cyhalothrin	Reduced
Imidacloprid	Reduced and altered
Binary mixture	Interrupted

3.6 Integrated Behavioural Response

All four behavioural endpoints showed a similar pattern. Control animals remained normal, while the individual pesticide treatments caused noticeable changes. The binary mixture animals showed the strongest response they showed excessive mucus secretion, marked changes in valve movement, reduced foot activity, and interrupted siphoning.

4. Discussion

The present study showed clear behavioural changes in *L. marginalis* after 21-day exposure to lambda-cyhalothrin, imidacloprid and their binary mixture. The main changes involved mucus secretion, valve movement, foot activity and siphoning. The binary mixture produced the strongest behavioural response. These findings show that behavioural changes can provide useful indications of pesticide-related stress. No visible mucus secretion was observed in the control group, which had a score of 0. Both lambda-cyhalothrin and imidacloprid treatments showed moderate mucus production, with a score of 2. While the mixture-treated group showed excessive mucus secretion and had the highest score of 3. Similar increases in mucus secretion and shell closure have been reported earlier in pesticide-exposed *L. marginalis* (Kumar et al., 2012; Kumar et al., 2013). Mucus production may be a protective response to chemical irritation; however, the present study cannot confirm the exact physiological mechanism. Pesticide exposure also affected the normal movement of the shells. Similar behavioural changes following lambda-cyhalothrin exposure have been reported in aquatic organisms, including *Danio rerio* (Sharma et al., 2024). In the present study, mussels exposed to lambda-cyhalothrin kept their shells closed for longer periods and opened them only from time to time. Those exposed to imidacloprid showed irregular shell movements. The changes were more noticeable in the mixture group, where the mussels kept their shells closed for long periods or closed them completely. Normal shell movement helps bivalves filter water and remain in contact with their surroundings. Changes in

this behaviour can therefore help identify signs of environmental stress in bivalves (Vereycken & Aldridge, 2023). Foot activity was reduced in both individual pesticide treatments with the strongest reduction observed in the mixture group. Similar withdrawal of the foot after pesticide exposure has also been reported in *L. marginalis* (Raj & Suganthi, 2015). When foot activity decreases, the animal may find it harder to move and maintain its position, especially during prolonged exposure. Siphoning activity also changed in the present study. Control animals continued siphoning normally, while both individual pesticide treatments reduced this activity. In the mixture group, siphoning was interrupted. Siphoning helps bivalves filter water and obtain food. A continued reduction in this activity may therefore affect normal feeding. Behavioural changes may occur before severe mortality and can provide useful signs of contaminant stress in freshwater bivalves (Shiry et al., 2023; Egan et al., 2023; Hou et al., 2026). Recent studies have also found that exposure to several stressors can produce different responses from exposure to a single stressor. These differences include changes in behavioural and physiological responses in freshwater bivalves (Lozano et al., 2024; Guille et al., 2025; Ballesteros et al., 2026). However, the stronger behavioural response in the present mixture treatment alone cannot be taken as proof of synergism. Demonstrating synergism requires quantitative concentration-response analysis and an appropriate mixture-toxicity model. The present study also shows the value of repeated behavioural observations during chronic exposure. Similar behavioural changes in *L. marginalis* have been reported after exposure to other aquatic contaminants, supporting the use of behavioural responses as early indicators of toxic stress (Jagtap et al., 2020). Mucus secretion, valve activity, foot movement and siphoning were simple and visible endpoints. Together, they provided a broader picture of stress than any one observation alone. Recent work has also shown that video-based and automated behavioural monitoring can improve the assessment of toxicity in bivalves (Escobar-Calderón et al., 2022; Shen & Nuggeoda, 2022). Such responses are in line with earlier reports of pesticide-related stress in *L. marginalis* following monocrotophos exposure (Mundhe et al., 2016). Overall, these findings suggest that behavioural changes can be used alongside other measures to examine the effects of pesticides on freshwater organisms.

5. Conclusion

The current study demonstrated distinct behavioral alterations in *L. marginalis* after 21-day exposure to lambda-cyhalothrin, imidacloprid and their binary combination. The changes were documented in mucus secretion, valve movement, foot activity and siphoning. Individual pesticide treatments induced observable behavioral disturbances whereas the binary combination provoked the strongest overall response, encompassing increased mucus secretion, prolonged or total valve closure, decreased foot activity and

disrupted siphoning. These findings highlight behavioral responses as an appropriate, simple and non-invasive endpoint to identify pesticide-induced stress in freshwater bivalve species. Further experimental designs using quantitative video tracking and automated behavioral metrics could enhance the utility of *L. marginalis* as a behavioral biomonitoring model.

6. Statements and Declarations

Ethical Approval: The collection, handling and experimental exposure of *Lamellidens marginalis* were carried out following standard ethical guidelines for aquatic animal research. No endangered or protected species were used in the present study.

Conflict of Interest: The authors declare that they have no conflict of interest.

Funding statement: The authors declare that no financial support or external funding was received for this research.

Acknowledgements: Not Applicable

References

- Ahire, P. B., & Dethe, V. D. (2023). Evaluation of imidacloprid-induced toxicity and lipid peroxidation in the freshwater bivalve, *Lamellidens marginalis*. *International Journal of Aquatic Biology*, 11(2), 124–130. <https://doi.org/10.22034/ijab.v11i2.1902>.
- Ahire, P. B., & Khure, A. R. (2026). Study of Physico-Chemical Parameters of Selected Regions on the Darna River, District Nashik, Maharashtra, India. *Uttar Pradesh Journal of Zoology*, 47(8), 10–17. <https://doi.org/10.56557/UPJZO/2026/v47i85607>.
- Alvim, T. T., Santos, C., & Martinez, C. B. R. (2025). Combined effects of λ -cyhalothrin and imidacloprid formulated insecticides on the embryo-larval development of *Danio rerio*. *Ecotoxicology*, 34(6), 1116–1127. <https://doi.org/10.1007/s10646-025-02902-y>.
- Ballesteros, M. L., Reyna, P. B., Alurralde, G., Gonzalez, M., Pegoraro, C., & Torre, L. (2026). Biomarker profiles reveal combined effects of a heatwave and a pesticide pulse in the freshwater bivalve *Corbicula largillierti*. *Aquatic Toxicology*, 296, 107842. <https://doi.org/10.1016/j.aquatox.2026.107842>.
- Berthelot, N., Palos Ladeiro, M., Orquevaux, M., Chaperon, B., Pochet, C., & Geffard, A. (2025). Effects of chemicals on mobility in the bivalve mollusc *Dreissena polymorpha*. *Aquatic Toxicology*, 286, 107482. <https://doi.org/10.1016/j.aquatox.2025.107482>.
- Egan, N., Stinson, S. A., Deng, X., Lawler, S. P., & Connon, R. E. (2023). Swimming behavior of *Daphnia magna* is altered by pesticides of concern, as components of agricultural surface water and in acute exposures. *Biology*, 12(3), 425. <https://doi.org/10.3390/biology12030425>.
- Escobar-Calderón, J. F., Chmíst-Sikorska, J., & Douda, K. (2022). High-frequency video analysis extends beyond the capabilities of valvometry in acute behavioral disturbance detection in bivalves. *Ecological Indicators*, 136, 108656. <https://doi.org/10.1016/j.ecolind.2022.108656>.
- Guille, A. G., Purnell, S., Lohery, S., & Ciocan, C. (2025). CLAMity: Mixtures of agricultural pesticides as multiple

- stressors in a bivalve species. *Journal of Hazardous Materials*, 483, 136692. <https://doi.org/10.1016/j.jhazmat.2024.136692>.
- Hartmann, J. T., Beggel, S., Auerwald, K., Stoeckle, B. C., & Geist, J. (2016). Establishing mussel behavior as a biomarker in ecotoxicology. *Aquatic Toxicology*, 170, 279–288. <https://doi.org/10.1016/j.aquatox.2015.06.014>.
- Hou, Y.-X., Tang, S.-Y., Liu, W., Li, Z.-T., Wei, K.-J., Hong, X.-S., Qin, J.-H., & Zha, J.-M. (2026). Chronic paracetamol exposure disrupts behavior and induces intrinsic apoptosis in a freshwater bivalve. *Environmental Pollution*, 405, 128582. <https://doi.org/10.1016/j.envpol.2026.128582>.
- Jagtap, J. T., Ubarhande, S. B., & Shejule, K. B. (2020). Behavioral changes in fresh water bivalve, *Lamellidens marginalis* due to acute toxic effect of organotin tributyltin chloride in summer season. *International Journal of Zoology and Applied Biosciences*, 5(4), 199–202. <https://doi.org/10.5281/zenodo.3996434>.
- Kumar, S., Pandey, R. K., Das, S., & Das, V. K. (2012). Acute toxicity and behavioural responses of a freshwater mussel *Lamellidens marginalis* (Lamarck) to dimethoate exposure. *Recent Research in Science and Technology*, 4(11), 39–45.
- Kumar, S., Pandey, R. K., Das, S., & Das, V. K. (2013). Temperature dependent mortality and behavioral changes in a freshwater mussel *Lamellidens marginalis* to dimethoate exposure. *Journal of Environmental Biology*, 34(2), 165–170.
- Lozano, V. L., Paolucci, E. M., Sabatini, S. E., Noya Abad, T., Muñoz, C., Liquin, F., Hollert, H., & Sylvester, F. (2024). Assessing the impact of imidacloprid, glyphosate, and their mixtures on multiple biomarkers in *Corbicula largillierii*. *Science of the Total Environment*, 942, 173685. <https://doi.org/10.1016/j.scitotenv.2024.173685>.
- Matsuda, K., Buckingham, S. D., Kleier, D., Rauh, J. J., Grauso, M., & Sattelle, D. B. (2001). Neonicotinoids: insecticides acting on insect nicotinic acetylcholine receptors. *Trends in Pharmacological Sciences*, 22(11), 573–580. [https://doi.org/10.1016/S0165-6147\(00\)01820-4](https://doi.org/10.1016/S0165-6147(00)01820-4).
- MPCB. (2025). *Polluted River Stretches / Priority River Stretch Monitoring: Darna River, Maharashtra*. Maharashtra Pollution Control Board. <https://mpcb.gov.in/>
- Mundhe, A. Y., Bhilwade, H., & Pandit, S. V. (2016). Genotoxicity and oxidative stress as biomarkers in fresh water mussel, *Lamellidens marginalis* (Lam.) exposed to monocrotophos. *Indian Journal of Experimental Biology*, 54(12), 822–828.
- Pandit, S. V., & Mundhe, A. Y. (2013). Monocrotophos induced behavioral stress, biochemical and histological alterations in *Lamellidens marginalis* (Lamarck). *The Bioscan*, 8(3), 1053–1056.
- Raj, T. G. J., & Suganthi, A. S. (2015). Toxic effect of monocrotophos on the foot of the freshwater mussel, *Lamellidens marginalis*. *Cross Current International Journal of Research*, 6(2).
- Saha, R., & Dutta, S. M. (2024). Pesticides' mode of action on aquatic life. *Toxicology Reports*, 13, 101780. <https://doi.org/10.1016/j.toxrep.2024.101780>.
- Sharma, D., Sarmah, R., Sarmah, R., Pokhrel, H., Bhagabati, S. K., Sarma, D. K., Patowary, A. N., & Mili, K. (2024). Lambda-cyhalothrin induced behavioural, neurotoxic and oxidative stress on vertebrate model *Danio rerio*. *Ecotoxicology*, 33, 663–676. <https://doi.org/10.1007/s10646-024-02763-x>.
- Shen, H., & Nugegoda, D. (2022). Real-time automated behavioural monitoring of mussels during contaminant exposures using an improved microcontroller-based device. *Science of the Total Environment*, 806, 150567. <https://doi.org/10.1016/j.scitotenv.2021.150567>.
- Shiry, N., Derakhshesh, N., Alavinia, S. J., Pouladi, M., Falco, F., & Faggio, C. (2023). *Anodonta cygnea*, a freshwater swan mussel, exposed to diazinon: toxicity thresholds in behaviour and physiology. *Veterinary Research Communications*, 47, 1303–1319. <https://doi.org/10.1007/s11259-023-10078-1>.
- Soderlund, D. M. (2012). Molecular mechanisms of pyrethroid insecticide neurotoxicity: recent advances. *Archives of Toxicology*, 86(2), 165–181. <https://doi.org/10.1007/s00204-011-0726-x>.
- Vereycken, J. E., & Aldridge, D. C. (2023). Bivalve molluscs as biosensors of water quality: state of the art and future directions. *Hydrobiologia*, 850, 231–256. <https://doi.org/10.1007/s10750-022-05057-7>.