

1     **FEEDING EFFICIENCY OF LARVIVOROUS FISH**  
2             **ON MOSQUITO LARVAE: A COMPARISON**  
3     **BETWEEN INDIGENOUS AND EXOTIC SPECIES**  
4                     **IN ASSAM, INDIA**

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**ABSTRACT**

**Aims:** The study aims to compare the feeding efficiency of three indigenous and two exotic fish species commonly available in the Northeastern region of India, using 4th instar mosquito larvae as prey, under controlled conditions in aquaria. The objective was to identify the most effective species of fish for potential use as biocontrol agents of mosquitoes.

**Study Design:** The design is based on an experimental comparative study. The predatory efficiency of each of the selected fish species was determined using a 5L transparent aquarium.

**Place and duration of the study:** The experimental setup for the present experiment was located at Dergaon Chariali, Golaghat, Assam, India, from March to June, 2025

**Methodology:** *Heteropneustes fossilis*, *Mystus vittatus*, and *Anabas testudineus* were the indigenous fish species and *Hyphessobrycon flammeus* and *Carassius auratus* were the exotic ornamental fish species chosen for this study. The indigenous species were collected from natural water bodies with the help of local fishermen, while the exotic species were procured from a neighboring aquarium store. Fourth instar larvae of mosquitoes were collected and used as prey at different densities (20, 50, 100, 200 larvae per aquarium). Each species was subjected to a feeding trial in replicates, and the number of consumed larvae was calculated to assess the feeding efficiency.

**Results:** The indigenous fish species *H. fossilis* exhibited significantly higher predation efficiency (76.5% at highest density), followed by *M. vittatus* and *A. testudineus*. On the other hand, the exotic species showed minimal larval predation with *C. auratus* and *H. flammeus* consuming only 4.5% and 1.5% respectively at the highest density.

**Conclusion:** From the present experiment, we concluded that the indigenous species of fish, particularly *H. fossilis* and *M. vittatus*, are promising candidates for use as biocontrol agents of mosquitoes in control and natural water bodies. Further study is recommended to determine the ecological viability of these species in an integrated vector management programme.

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**Keywords:** *Indigenous, exotic, feeding, efficiency, mosquito larvae, fish*

## 17 1. INTRODUCTION

18

19 Since the turn of the century, mosquitoes have remained one of the most serious threats to  
20 humanity, acting as vectors for some dreaded diseases, including malaria, chikungunya,  
21 dengue, yellow fever, Japanese encephalitis (JE), and filariasis. The World Health  
22 Organization (WHO, 2019) estimates that mosquito-borne infections impact about 700  
23 million people each year in Africa, Asia, and Central and South America, resulting in more  
24 than one million deaths. In the northeastern states of India, mosquito-borne illnesses such  
25 as malaria, Japanese encephalitis, lymphatic filariasis, and dengue are serious public health  
26 issues. Presently, JE and malaria are the most frequent diseases among these, and they  
27 spread throughout the state of Assam (Hazarika and Sadhukhan, 2024). A comprehensive  
28 understanding of mosquito bionomics is critically essential for the development of an  
29 effective vector control strategy. Studies related to the interaction between mosquitoes and  
30 the pathogens they transmit, ecological interactions of mosquitoes with their natural  
31 predators and other components of an ecosystem are of utmost importance for successful  
32 control. There is habitat specificity in each genus of mosquito, and they reproduce in slow-  
33 moving or stagnant water. Clean water sources, including ponds, streams, and marshes, are  
34 preferred by *Anopheles* mosquitoes, the vector of malaria (Herrel et al., 2001). Chikungunya  
35 and Rift Valley fever (RVF) are spread by *Mansonia* species, which deposit their eggs on the  
36 surfaces of aquatic plants, particularly floating vegetation (Service, 2012). The genus *Culex*  
37 is responsible for zoonotic viral transmission (Madhab et al., 2024), playing a critical role in  
38 the transmission of JE and West Nile Virus, lay their eggs in rafts on still water (Jackson,  
39 2004). The *Aedes* mosquitoes, primarily *Aedes aegypti* and *Aedes albopictus*, are container  
40 breeders in clean and stagnant water, the primary vectors of Dengue or Dengue  
41 Haemorrhagic Fever (WHO, 2024). For the control of these vector mosquitoes, chemical  
42 pesticides are traditionally used as the primary method. The major drawback of using  
43 chemical pesticides is the development of resistance in mosquitoes against the pesticides, in  
44 addition to major environmental consequences such as environmental pollution, the  
45 elimination of non-target beneficial species, and the bioaccumulation of toxic residues in  
46 other organisms, including humans (Novak & Lampman, 2001). On the other hand, using  
47 natural predators such as larvivorous fish as bio-control agents is a safer and  
48 environmentally friendly option. The larvivorous fish feeds on mosquito larvae and naturally  
49 controls the mosquito population (Mohamed, 2003; Yildirim & Karachuha, 2007). The most  
50 common features of larvivorous fish on mosquito larvae are their small size, hardiness in  
51 nature, and their ability to thrive in shallow, contaminated water bodies where the majority of  
52 the mosquito species commonly breed. They should also have drought tolerance, prolific  
53 breeding, and the ability to thrive in confined water without compromising its quality (Gupta  
54 et al., 1992). In India, *Poecilia reticulata*, commonly known as the guppy and *Gambusia*  
55 *affinis*, commonly known as the mosquito fish, are the most popular species for mosquito  
56 control (Chatterjee & Chandra, 1997). Their invasive nature is a major threat to the  
57 indigenous species, particularly for food and habitat. However, ornamental fish, whether  
58 indigenous or exotic, can contribute to the suppression of larval mosquitoes when reared in  
59 controlled conditions (Davis et al., 2019). In this context, comparing the feeding efficiency of  
60 indigenous and exotic larvivorous fish is critically essential for selecting the most effective  
61 and ecologically suitable species.

62 Comparative studies on the feeding efficiency of indigenous versus exotic ornamental fish  
63 are limited in the northeastern region of India, in general, and in the state of Assam, in  
64 particular. We selected five species of larvivorous fish: three indigenous fish species  
65 commonly available in Assam, namely *Heteropneustes fossilis* Bloch, *Mystus vittatus* Bloch,  
66 and *Anabas testudineus* Bloch, and two exotic species, *Hyphessobrycon flammeus* Myers  
67 and *Carassius auratus* Linnaeus to evaluate their comparative larval feeding efficiency under  
68 controlled laboratory conditions. Our primary aim is to identify the most efficient larvivorous

69 fish species suitable for the biological control of mosquitoes in natural and semi-natural  
70 aquatic habitats.

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## 73 **2. MATERIAL AND METHODS**

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### 75 **2.1 Collection of Fishes and Mosquito Larvae**

76 The study was conducted in Dergaon Chariali, Golaghat, Assam, India, during the period of  
77 March to June 2025. *H. fossilis*, *M. vittatus*, *A. testudineus*, *H. flammeus*, and *C. auratus*  
78 were the five fish species chosen for this study. The indigenous fish species, namely *H.*  
79 *fossilis*, *M. vittatus*, and *A. testudineus*, were collected from the rice field and irrigation canal  
80 near Dergaon Chariali, Golaghat, with the assistance of local fishermen. Live specimens of  
81 *H. fossilis* and *M. vittatus* were also procured from the local fish market at Dergaon Chariali.  
82 The other two selected species, namely *H. flammeus* and *C. auratus*, are exotic ornamental  
83 fish species, highly preferred by the people of this locality for aquarium, and they were  
84 brought from the local aquarium store.

85 We collected *Culex* larvae from a domestic sewage drain near Naharani Chariali, Dergaon,  
86 Golaghat, Assam. Dippers and sieves were used to collect the larvae. Collected larvae were  
87 transported to the experimental arena in plastic containers and thoroughly cleaned with tap  
88 water to remove debris. The larvae were sorted into different larval instars on the basis of  
89 their size and morphological features (WHO, 2005); the fourth instar larvae were used as  
90 prey for larvivorous fish. The larvae were maintained in a glass container with sufficient  
91 aeration (9cm diameter) and fed with powdered yeast.

### 92 **2.2 Acclimatization and Maintenance of Fishes**

93 In the experimental site, both the indigenous and exotic fish species were kept in 5L capacity  
94 glass aquaria (30 × 20 × 20 cm) at a stocking density of four fish per tank. Water  
95 temperature within the aquarium tank was maintained at  $27 \pm 2^\circ\text{C}$ , and the fish were  
96 exposed to light for 12 hours followed by a complete 12 hours of darkness (12L:12D).  
97 Aeration of the aquarium was maintained continuously for a sufficient supply of oxygen. The  
98 fish species were acclimatized to the aquarium environment for one week before  
99 experimentation. During those days, they were fed fish pellets once daily. Before  
100 experimentation and starting rearing in the aquarium, all the selected fish species for the  
101 experiment were subjected to bath treatment in potassium permanganate (KMnO<sub>4</sub>) solution  
102 (1mg/L) for four hours to eliminate any external pathogens (APHA, 2005).

### 103 **2.3 Experimental Design**

104 The predatory efficiency of each of the selected fish species was determined using a 5L  
105 transparent aquarium. Five replicates of each experiment for each species were carried out.  
106 The selected indigenous and exotic species were fasted for 24 hours before being released  
107 into the experimental setup so that the hunger level of each species was standardized.

108 To assess the predation efficiency of the fishes, the following prey densities of fourth instar  
109 *Culex* larvae were used: 20, 50, 100, and 200 larvae per aquarium, corresponding to Days 1  
110 through 4, respectively. After introducing the larvae into each aquarium, the number of  
111 remaining live larvae was counted after 24 hours. The difference between the number of  
112 larvae introduced and the number that remained was used to determine how many larvae  
113 were consumed. According to the accepted larvivorous fish feeding trial approach, missing

114 larvae were assumed to be consumed by the fish (Chandra et al., 2008; Bano &  
 115 Krishnamurthy, 1974). To ensure water quality, aquaria were cleaned, and their water was  
 116 replaced every day with dechlorinated tap water. Throughout the trial, only mosquito larvae  
 117 were given as food.

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### 120 3. RESULTS AND DISCUSSION

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122 In the present study, we examined the predatory potential of the selected fish species at a  
 123 range of prey densities, with the prey being mosquito larvae in their fourth instars. The  
 124 effects of larval density on eating behaviour were investigated at prey densities of 20, 50,  
 125 100, and 200. Each fish was kept in a 5L glass tank, and the number of larvae eaten after 24  
 126 hours was recorded. Each trial was replicated ten times for each fish species.

127

128 In the present investigation, it was found that there is a clear variation in larval consumption,  
 129 with indigenous fish (*H. fossilis*, *M. vittatus*, and *A. testudineus*) showing significantly higher  
 130 feeding efficiency on the mosquito larvae compared to exotic fish (*C. auratus* and *H.*  
 131 *flammeus*). The feeding activity increased with increasing larval density, indicating a positive  
 132 density-dependent reaction, which is important in controlling mosquito epidemics in larval-  
 133 rich habitats (Tables 1, 2, 3, and 4).

134

135 At the lowest prey density (20), indigenous species established moderate predation  
 136 efficiency. The exotic ornamental fish had a poor feeding response, with *H. flammeus* not  
 137 consuming any larvae (Table 1). All indigenous species consumed more larvae when prey  
 138 density increased to 50. *H. fossilis* once again showed the best efficiency (35/50, number of  
 139 larvae consumed/total number of larvae fed), followed by *M. vittatus* (28/50) and *A.*  
 140 *testudineus* (17/50). In the case of exotic species, *C. auratus* consumption improved slightly  
 141 (3/50), whereas *H. flammeus* remained passive (Table 2).

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144 **Table 1. Larval Consumption at Prey Density of 20 Larvae per Aquarium**

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Fish Species	Larvae Supplied	Larvae Consumed	Consumption (%)
<i>Heteropneustes fossilis</i>	20	11	55%
<i>Mystus vittatus</i>	20	9	45%
<i>Anabas testudineus</i>	20	7	35%
<i>Carassius auratus</i>	20	1	5%
<i>Hyphessobrycon flammeus</i>	20	0	0%

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148 **Table 2. Larval Consumption at Prey Density of 50 Larvae per Aquarium**

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Fish Species	Larvae Supplied	Larvae Consumed	Consumption (%)
<i>Heteropneustes fossilis</i>	50	35	70%
<i>Mystus vittatus</i>	50	28	56%
<i>Anabas testudineus</i>	50	17	34%
<i>Carassius auratus</i>	50	3	6%
<i>Hyphessobrycon flammeus</i>	50	0	0%

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152 With the increased prey density 100, it is observed that the predation rate of the indigenous  
 153 fish species increased significantly. Indigenous fish species remained efficient, with *M.*  
 154 *vittatus* (64/100) demonstrating better performance, while the *H. fossilis* performing the best  
 155 (72/100). Exotic ornamental fish demonstrated limited predation, (*C. auratus*-7/100; *H.*  
 156 *flammeus*-1/100) indicating that they are less receptive or capable of consuming mosquito  
 157 larvae, as indicated in Table 3.

158  
 159 **Table 3. Larval Consumption at Prey Density of 100 Larvae per Aquarium**

Fish Species	Larvae Supplied	Larvae Consumed	Consumption (%)
<i>Heteropneustes fossilis</i>	100	72	72%
<i>Mystus vittatus</i>	100	64	64%
<i>Anabas testudineus</i>	100	37	37%
<i>Carassius auratus</i>	100	7	7%
<i>Hyphessobrycon flammeus</i>	100	1	1%

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163

164 All of the native fish species improved their predatory efficiency at the highest larval density  
 165 in the current experimental setting (prey density 200), with *H. fossilis* and *M. vittatus* in  
 166 particular showing their better predation efficiency. Even with a large number of larvae, the  
 167 exotic ornamental species once again demonstrated low efficiency, indicating their poor  
 168 ability for controlling mosquitoes (Table 4).

169

170 **Table 4. Larval Consumption at Prey Density of 200 Larvae per Aquarium**

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Fish Species	Larvae Supplied	Larvae Consumed	Consumption (%)
<i>Heteropneustes fossilis</i>	200	153	76.5%
<i>Mystus vittatus</i>	200	138	69%
<i>Anabas testudineus</i>	200	74	37%
<i>Carassius auratus</i>	200	9	4.5%
<i>Hyphessobrycon flammeus</i>	200	3	1.5%

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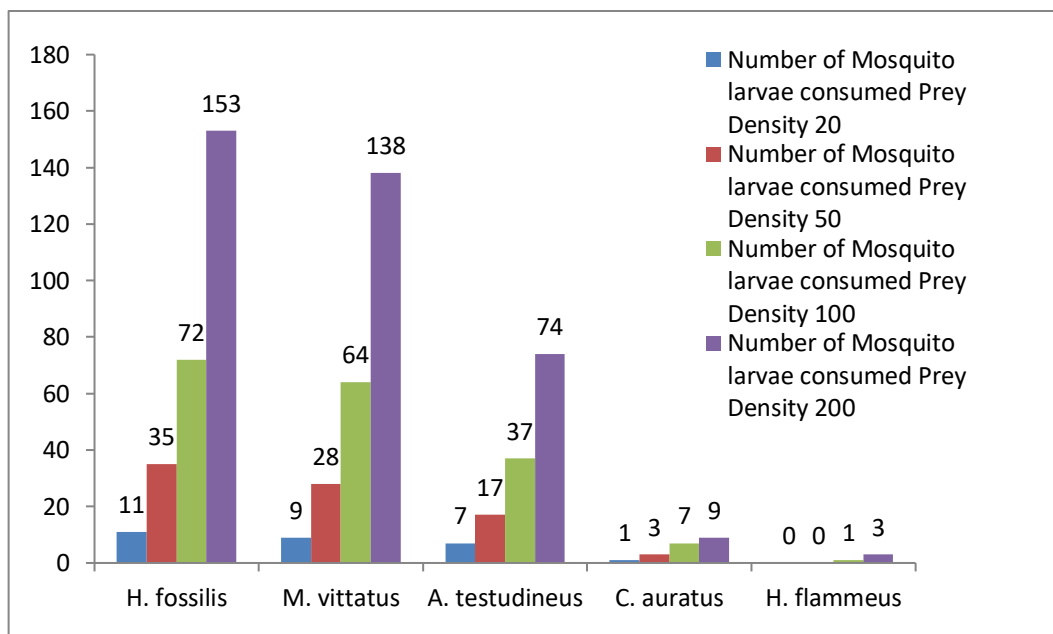
174

175 In our experiment, it is found that *H. fossilis* is the best performer across all prey densities. At  
 176 the highest, as per the present experimental set up the fish species consumed 153 larvae  
 177 (76.5%) as shown in the Table 4. The upward tendency of the species towards consumption  
 178 of mosquito larvae in a controlled setting like an aquarium again established its potential to  
 179 be used as a biocontrol agent of mosquitoes. It will be good choice for integrated mosquito  
 180 control as the species can be used in big, open and shallow water bodies where mosquitoes  
 frequently breed.

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186 **Figure 1. Bar diagram showing the number of mosquito larvae consumed by the**  
 187 **selected fish species at different prey density**

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189 In the present experimental condition, *M. vittatus* is found to be the second highest  
 190 consumer, reaching 138 larvae at maximum density (69%). It also exhibited a similar positive  
 191 prey density response as *H. fossilis*, but was slightly less aggressive. Like *H. fossilis*, *M.*  
 192 *vittatus* is a bottom and mid-column feeder, adapted to hunting in dark areas, which are ideal  
 193 mosquito habitats, establishing it as an efficient bio-control agent of mosquitoes. *A.*  
 194 *testudineus* is a commonly available fish species in the paddy field, irrigation canals and in  
 195 the wetlands of the northeastern region of India and the state of Assam in particular. In our  
 196 experiment, the species' performance is moderate, with 74 larvae consumed at the highest  
 197 density (37%). The air-breathing fish is also found to be a moderate mosquito control agent  
 198 in aquatic bodies in comparison to *H. fossilis* and *M. vittatus*.

199

200 *C. auratus*, commonly known as the goldfish, is a highly preferred exotic ornamental species  
 201 for aquariums in Assam. However, our experiment demonstrates its limited ability to control  
 202 mosquitoes. Even at the highest larval density (200) in the present investigation, it  
 203 consumed only 9 larvae (4.5%), indicating very low feeding efficiency. The species is  
 204 primarily selected for aquarium culture due to its aesthetic value, and it is a scavenger in its  
 205 food habits. It does not possess the capacity to recognize mosquito larvae as a preferred  
 206 source of food due to its slow swimming behaviour, reducing their effectiveness as  
 207 predators. Thus, while goldfish enhance visual appeal in an aquarium, their utility in  
 208 biological mosquito control is minimal. In the present study, it has been observed that the  
 209 exotic ornamental fish species *H. flammeus* exhibits the lowest feeding preference for  
 210 mosquito larvae, larval consumption remaining close to zero across all prey densities. It is  
 211 small in size, and a slow-moving ornamental fish, and it has been observed that it feeds  
 212 mainly on fine detritus and plankton rather than hunting prey. Its poor performance indicates

213 that it is not a suitable candidate for mosquito control and may not be considered a reliable  
214 species in the biological control of mosquitoes.

215 The monsoon season typically encounters high mosquito larval densities in India, particularly  
216 in the northeastern states. As observed in our experiment, all the indigenous species of fish  
217 increase their feeding efficiency in proportion to the prey density. As such, these species are  
218 highly valuable as natural controlling agents of mosquito larvae during the monsoon season.  
219 The present findings corroborate the study of Ghosh et al. (2005) and Ritchie and  
220 Laidlawbell (1994), showing that fish predation could significantly reduce mosquito  
221 population in larval-rich habitats. The results of the present investigation highlight the  
222 possible use of indigenous fishes in mosquito control. The selected species are well-adapted  
223 to local environmental conditions, particularly in Assam, and are highly responsive to prey  
224 movement and density. In contrast, the exotic ornamental fishes are found to be ineffective  
225 and thus incompatible for use in practical vector control operations, particularly against  
226 mosquitoes. *G. affinis* and *P. reticulata*, two popular exotic ornamental fish species in  
227 Assam, are not part of this study; a previous study carried out by Rupp (1996) indicates their  
228 invasive nature, often out-competing the indigenous species. The present investigation  
229 highlights the possible replacement of exotic varieties of fish species with commonly  
230 available indigenous species for mosquito control. The results of the investigation  
231 demonstrated that all three selected indigenous species possess significantly higher  
232 predatory efficiency against *Culex* larvae in comparison to exotic species. Among all the  
233 indigenous ornamental species, *H. fossilis* is found to be the top performer in predation of  
234 mosquito larvae. The result is consistent with the findings of Rupp (1996), who suggested  
235 the use of native fish species over exotic species for mosquito control. As found in our  
236 investigation, the increasing number of larval predation with higher prey densities  
237 corroborates findings of Ghosh et al. (2005) and Willems et al. (2005), establishing a positive  
238 correlation between the feeding rate and prey density. Light availability is another important  
239 factor controlling the feeding behavior of fish as indicated by Jacob et al. (1983) and Russel  
240 et al. (2001). In the present study, it is observed that larval consumption rate of the  
241 indigenous species is generally higher during daylight, which suggests that the fish species  
242 use visual keys for detection of prey. Our finding is also supported by the study carried out  
243 by Oo et al. (2018) and Noreen et al. (2017) suggesting decreased predation rate during  
244 night.

245 It is already established that biological control of pest populations using natural enemies  
246 offers several benefits over the use of chemical pesticides. Biocontrol mechanisms are  
247 environmentally safe without damaging non-targets, and there is no issue of development of  
248 resistance, which is an important feature of all insect pests, including mosquitoes (Yap et al.,  
249 1985). The main challenges in using indigenous or exotic fish species as mosquito biocontrol  
250 agents are the species-specific habitat requirements, followed by proper maintenance, which  
251 must be addressed (Das & Amalraj, 1997). Considering the high feeding efficiency of *H.*  
252 *fossilis* and *M. vittatus*, the introduction of these species in different aquatic habitats,  
253 including rice fields, drains, pools, ditches, and ponds, is highly recommended for effective  
254 control of mosquito larvae. To verify their long-term efficacy and ecological effects in an  
255 aquatic ecosystem, more field-based research and observation are required.

256

#### 257 **4. CONCLUSION**

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259 The present investigation recommends the introduction of indigenous ornamental fish  
260 species as biocontrol agents of mosquitoes. These are playing a crucial role in our  
261 environment in naturally controlling the mosquito population, which are vectors of some fatal  
262 illnesses including malaria, dengue and Japanese encephalitis. Incorporation of these locally

263 available species into mosquito breeding sites such as stagnant water bodies, sewage  
264 drains, rice fields and village ponds will significantly reduce the mosquito population.  
265 Indigenous species such as *H. fossilis* and *M. vittatus* are found to be the promising  
266 candidates for biological control of mosquitoes in the northeastern region of India, a  
267 mosquito-endemic region.

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#### 271 **DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

272

273 Author(s) hereby declare that NO generative AI technologies such as Large Language  
274 Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used  
275 during writing or editing of this manuscript .The authors acknowledge the use of AI tools for  
276 improving the structure and framing of sentences only.

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