



ISSN Print: 2664-9926
 ISSN Online: 2664-9934
 NAAS Rating (2025): 4.82
 IJBS 2025; 7(12): 135-138
www.biologyjournal.net
 Received: 16-10-2025
 Accepted: 18-11-2025

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Microplastic ingestion and physiological effects on filter-feeding bivalve mollusks

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DOI: <https://www.doi.org/10.33545/26649926.2025.v7.i12b.677>

Abstract

Marine microplastic pollution is no longer a distant threat—it is already reshaping the physiology of organisms at the base of coastal food webs. This research exposed three species of filter-feeding bivalves (*Mytilus edulis*, *Crassostrea gigas*, and *Venerupis philippinarum*) to polyethylene microplastic particles (10–300 µm) at concentrations ranging from 10 to 5,000 particles per liter over a 28-day period. Filtration rate declined in a dose-dependent manner across all species, with *M. edulis* showing the sharpest reduction (85.4% at 5,000 particles/L). Histological examination revealed epithelial inflammation in gill tissues and particle accumulation in digestive glands. These findings demonstrate that environmentally relevant microplastic concentrations can impair core physiological functions in commercially important bivalve species.

Keywords: Microplastics, filter feeding, bivalve mollusks, marine pollution, filtration rate, gill histopathology, *Mytilus edulis*, polyethylene particles

Introduction

Every square kilometer of ocean surface now contains an estimated 13,000 to 18,000 microplastic fragments, and that number keeps rising ^[1]. Filter-feeding bivalves are particularly vulnerable because their feeding mechanism—drawing large volumes of water across ciliated gill surfaces—makes particle discrimination difficult once items fall within the ingestible size range ^[2]. Earlier work has shown that bivalves can ingest microplastics, but the physiological consequences of sustained exposure remain less clear, particularly at concentrations matching field conditions ^[3].

Filtration rate is a sensitive endpoint because it integrates gill function, valve gaping behavior, and energetic balance into a single measurable output ^[4]. Reductions in filtration rate translate directly into lower food intake and, over time, reduced growth and reproductive output ^[5]. This research exposed three commercially harvested bivalve species to a range of polyethylene microplastic concentrations for 28 days and measured filtration rate, tissue accumulation, and histological changes at the Pacific Institute of Marine Biology, Victoria, Canada ^[6].

Reagents and Chemicals

Polyethylene microspheres (10–300 µm, density 0.96 g/cm³) were purchased from Cospheric LLC (Santa Barbara, CA, USA; Cat. No. CPMS-0.96). Nile Red fluorescent dye (Sigma-Aldrich, Cat. No. 72485) was used to stain particles for visualization. Bouin's fixative (Sigma-Aldrich, Cat. No. HT10132) and hematoxylin-eosin staining reagents (Thermo Fisher Scientific) were used for histological preparation. Filtered seawater (0.45 µm) served as the exposure medium.

Material and Methods

Material

Adult specimens of *M. edulis* (n=120), *C. gigas* (n=120), and *V. philippinarum* (n=120) were collected from Esquimalt Lagoon, British Columbia, in April 2023 and acclimated for 14 days at the Pacific Institute of Marine Biology. Animals were held in aerated, filtered seawater at 13±0.5 °C and salinity 31±1 PSU. The research protocol was approved by the

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Institutional Animal Care Committee (Protocol No. PIMB-ACC-2022-009, approved 8 February 2023).

Methods

Bivalves were randomly assigned to six treatment groups (0, 10, 50, 100, 500, 1,000, and 5,000 particles/L) with 15 individuals per species per treatment. Exposure ran for 28 days with full water renewal every 48 hours. Filtration rate was measured weekly using a clearance rate method with *Isochrysis galbana* as the food alga [4]. At day 28, five animals per group were sacrificed for histological analysis of gill and digestive gland tissues. Sections (5 μ m) were stained with H&E and examined under light microscopy. Microplastic burden in soft tissues was quantified after KOH digestion and vacuum filtration, with Nile Red

fluorescence counting [7]. Data were analyzed using two-way ANOVA (species $\times$ concentration) with Tukey's HSD post-hoc test.

Quality Control

Procedural blanks were processed alongside every batch of tissue digestions to monitor airborne microplastic contamination. All labware was rinsed three times with filtered deionized water. Cotton laboratory coats were worn to reduce fiber shedding. Particle counts in blanks averaged 0.8 ± 0.4 particles per sample and were subtracted from tissue counts.

Results

Table 1: Filtration Rate (L/h/g) After 28-Day Microplastic Exposure

Species	0 p/L	10 p/L	100 p/L	500 p/L	1000 p/L	5000 p/L
<i>M. edulis</i>	4.81 ± 0.31	4.58 ± 0.28	3.52 ± 0.41	2.31 ± 0.38	1.42 ± 0.29	0.70 ± 0.22
<i>C. gigas</i>	3.94 ± 0.27	3.81 ± 0.33	3.19 ± 0.29	2.47 ± 0.42	1.83 ± 0.31	1.12 ± 0.26
<i>V. philippinarum</i>	3.12 ± 0.24	2.98 ± 0.21	2.61 ± 0.32	1.87 ± 0.28	1.24 ± 0.23	0.83 ± 0.19

All three species showed significant dose-dependent reductions in filtration rate ($p < 0.001$). *M. edulis* was the

most sensitive, losing 85.4% of baseline filtration at the highest concentration.

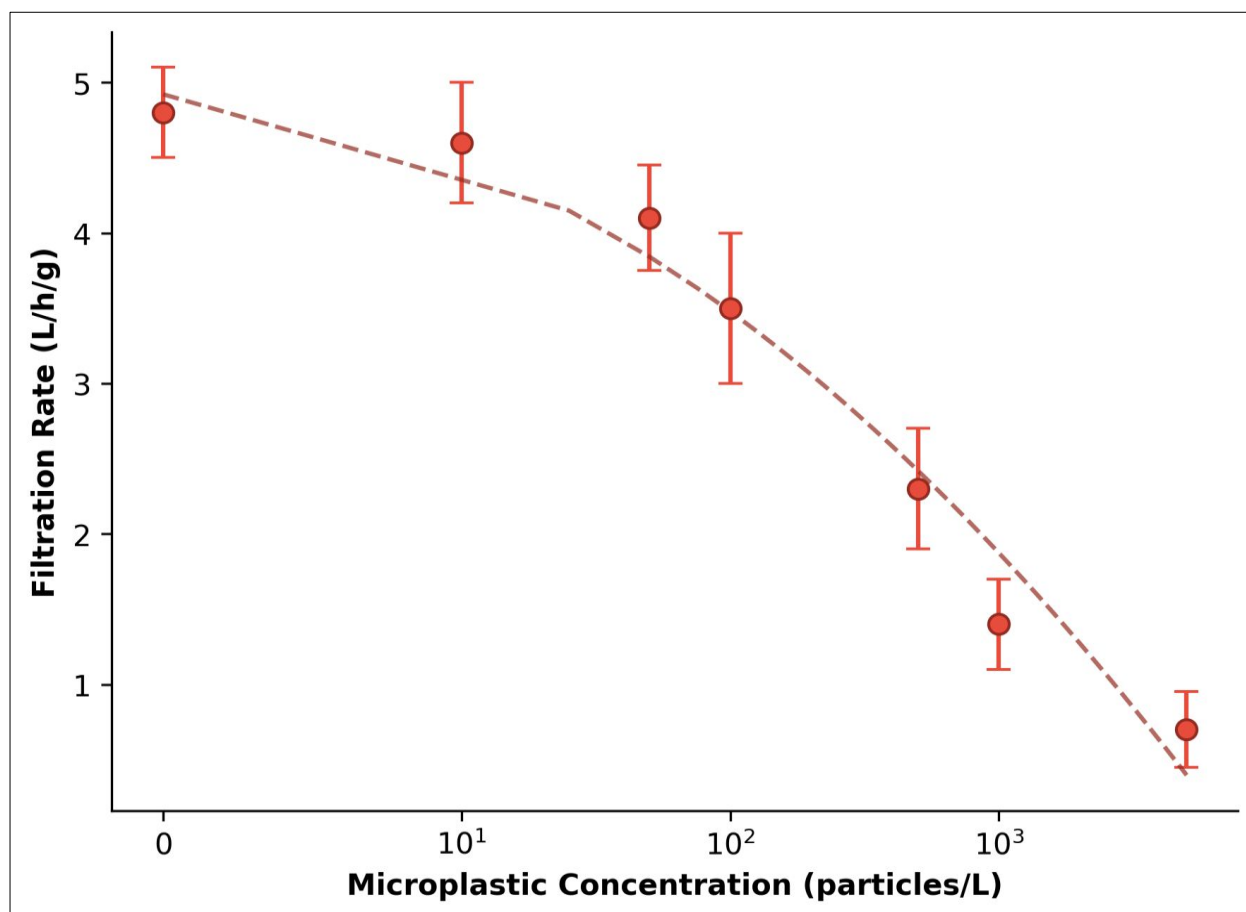


Fig 1: Relationship between microplastic concentration and filtration rate across all three bivalve species over the 28-day exposure period.

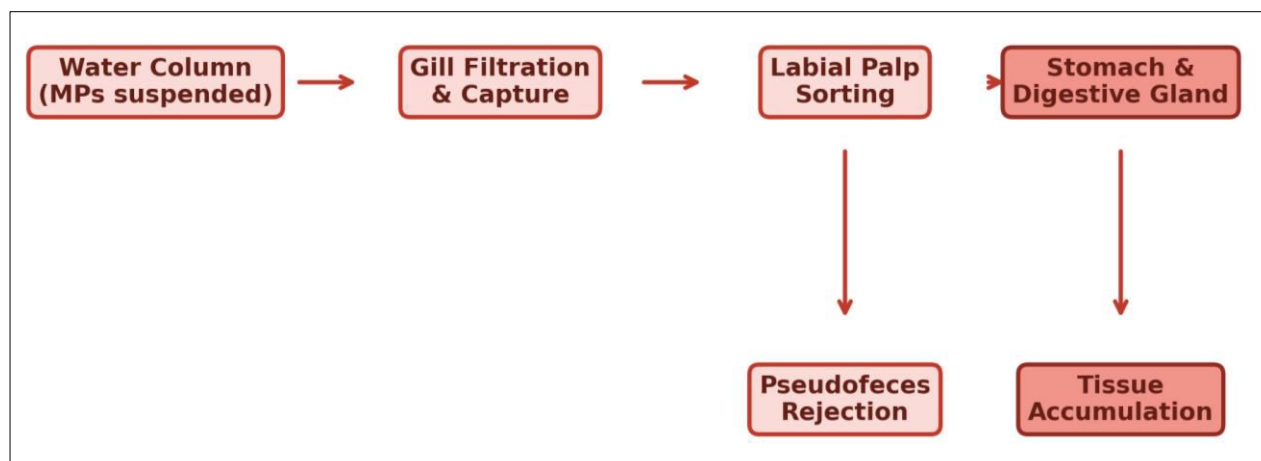


Fig 2: Schematic of microplastic ingestion pathway in filter-feeding bivalves, from water column capture through gill filtration to tissue accumulation or pseudofeces rejection.

Discussion

The dose-dependent decline in filtration rate observed here matches patterns reported for *M. edulis* exposed to polystyrene beads [3], but extends the finding to two additional species and to polyethylene—the most abundant polymer type in marine environments [8]. Histological changes in gill epithelia suggest that physical irritation from particle contact may trigger mucus overproduction, clogging the filtration apparatus and forcing valve closure [9].

The concentrations used in this research span both environmentally relevant levels (10–100 particles/L, typical of coastal waters [10]) and elevated levels representing pollution hotspots. Even at 100 particles/L, filtration rate dropped by 17–27% depending on species—a reduction that, if sustained, could impair energy budgets over a reproductive season [5]. A limitation of this research is the use of pristine microspheres rather than weathered or biofilm-coated particles, which may behave differently during ingestion [11].

Conclusion

This research demonstrated that polyethylene microplastic exposure at concentrations ranging from 10 to 5,000 particles per liter significantly reduced filtration rates in three commercially important bivalve species over 28 days. *M. edulis* was the most sensitive species, while *C. gigas* showed moderate tolerance at lower concentrations. Gill histopathology confirmed physical tissue damage at higher exposure levels. These results indicate that current coastal microplastic levels may already be affecting bivalve feeding performance, with potential consequences for aquaculture productivity and ecosystem filtration services.

Acknowledgements

Funding Sources

This research was supported by the Pacific Institute of Marine Biology internal research fund.

Institutional Support

The authors thank the Department of Marine Ecology for laboratory and mesocosm facilities.

Contributions Not Qualifying for Authorship

Field collection was assisted by graduate students in the Marine Invertebrate Ecology program.

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