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Chronic Low-Frequency Anthropogenic Noise Induces Premature Egg Dropping and Behavioral Suppression in Red Cherry Shrimp (*Neocaridina davidi*)

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ABSTRACT

Chronic noise exposure may affect reproduction and behavior in freshwater crustaceans. This study examined embryo retention, behavioral activity, and exoskeletal coloration in red cherry shrimp (*Neocaridina davidi*) exposed to continuous 80 Hz acoustic-mechanical stimulation for 30 days. Three tanks per treatment, each containing 10 females and five males, were maintained under either noise exposure (120 dB re 1 µPa root mean square sound pressure) or quiet control conditions. Five females in each tank were initially berried. Noise-exposed tanks recorded 16.67 ± 2.08 detached embryos per tank, equivalent to 3.33 ± 0.42 per initially berried female, whereas controls recorded no detachment. A negative binomial generalized linear mixed model with a log link and tank as a random intercept indicated a significant treatment effect (β = +2.84, SE = 0.61, Z = 4.66, $p < 0.001$, 95% confidence intervals (CIs) [1.64, 4.04]). The coefficient and its CI are expressed on the natural-log scale. Exposed shrimp showed higher antennal flicking frequencies (22–28 versus 7–9 flicks/min; $p < 0.001$), reduced locomotion speed (β = −3.42 cm/s; $p < 0.001$), and increased appendage immobility (β = +35.2 s/min; $p < 0.001$). Pale coloration occurred in 19 of 30 exposed females (63.3%) and 11 of 30 controls (36.7%). These findings associate sustained acoustic-mechanical exposure with embryo detachment and altered activity in *N. davidi*. Limited tank replication and the absence of direct particle-motion and physiological measurements constrain interpretation of the underlying mechanisms.

1. INTRODUCTION

The global ornamental aquaculture industry has expanded significantly, increasingly prioritizing species that balance commercial viability with academic research [1]. In this growing sector, the red cherry shrimp (*Neocaridina davidi*) has emerged as a cornerstone species, driven by high demand in international trade markets and its significant economic impact [2]. The cultivation of *N. davidi* represents a highly profitable and operationally feasible business model, supported by empirical financial indicators such as favorable revenue-cost (R/C) and benefit-cost (B/C) ratios in small-scale hatchery environments [3].

The structural transition toward intensified production frameworks, including land-based monoculture and advanced recirculating aquaculture systems (RAS), has inadvertently introduced a distinct suite of environmental stressors into closed aquatic habitats. Anthropogenic noise, frequently characterized as a pervasive, "invisible" pollutant, has become a dominant byproduct of these intensive farming practices, primarily stemming from mechanical machinery operations and routine infrastructure maintenance [4]. While the physiological consequences of classic hydrochemical water parameters are thoroughly established, the direct impacts of artificial acoustic environments on crustacean health and welfare remain an overlooked, critical frontier of study [5, 6].

Despite the growing paradigm of vibroacoustic ecology, the systematic impact of human-made noise on decapod welfare and hatchery management protocols has historically been neglected [5, 6]. Compounding this neglect is the outdated assumption that aquatic invertebrates are ecologically deaf; however, contemporary research demonstrates that crustaceans possess a highly sophisticated evolutionary affinity for detecting and utilizing both sound waves and substrate-borne vibrations [6]. Current empirical evidence indicates that acoustic exposure is far from benign, capable of triggering severe physiological stress cascades, disrupting intra-species communication, altering essential foraging behaviors, and potentially inflicting irreversible anatomical micro-damage [4, 7].

The structural propagation of sound within aquatic media differs fundamentally from atmospheric transmission, facilitating the rapid conduction of vibratory cues essential to crustacean sensory biology [5, 6]. Underwater acoustic waves travel approximately 4.5 times faster than in air and experience minimal attenuation across distance, maximizing the physical efficiency of information transfer [5, 6]. This rapid, low-loss transmission enables macro-invertebrates to leverage

mechanoreception for critical ecological functions, including localized predator avoidance, conspecific recruitment, and microhabitat selection [6, 8].

Central to this physiological defense mechanism is the Crustacean Hyperglycemic Hormone (CHH), a critical neuropeptide synthesized and released by the X-organ/sinus gland complex in response to physical, chemical, or environmental disturbances [9-11]. Under stressful conditions, the CHH pathway acts as a primary metabolic regulator, facilitating the rapid mobilization of energy reserves by promoting the glycogenolysis of hepatopancreatic glycogen into hemolymphatic glucose to meet elevated metabolic demands [12, 13]. While acute activation of this system provides immediate physiological compensation, chronic noise exposure can lead to severe systemic strain. In larger decapods like *Callinectes sapidus* and *Homarus americanus*, exposure to low-frequency vessel noise and sonar triggers sustained increases in hemolymph glucose levels mediated by CHH, which can take anywhere from 48 hours to 7 days to return to baseline levels post-exposure [10, 14]. Prolonged or extreme stress may even result in hyperglycemia accompanied by a depletion of localized CHH levels, signaling endocrine exhaustion or rapid hormonal utilization within the organism [13].

This internal physiological strain directly manifests as clear macro-behavioral alterations and altered spatial distribution patterns. Recent laboratory investigations demonstrate that *N. davidi* possesses the capacity to perceive anthropogenic underwater noise, which significantly impacts individual orientation and localized movement [14]. When subjected to acoustic playbacks, these shrimps display a distinct spatial avoidance response, shifting their distribution to spend a significantly higher proportion of time in zones furthest from the sound source, even as overall locomotion speeds drop across both control and exposed groups [1]. Furthermore, anthropogenic noise functions as a severe cognitive distraction that heavily impairs foraging performance. Noise-exposed *N. davidi* exhibit a significantly higher latency to locate introduced food sources, complete fewer successful food-finding attempts, and demonstrate a reduced frequency of revisits to feeding sites [15]. Such acoustic interference disrupts the efficiency of sensory-mediated tasks, suggesting that human-made noise compromises the long-term metabolic fitness of the species. To track these long-term behavioral transitions and shifting competitive dynamics in decapods, modern bio-acoustic studies increasingly rely on high-resolution automated tracking software (EthoVision XT™) to accurately quantify activity levels and behavioral milestones over extended timelines [14].

Despite growing insights into the immediate behavioral consequences of acoustic pollution, a profound knowledge gap persists regarding its long-term carryover effects on crustacean phenotypic expression and reproductive output. Current scientific literature completely lacks empirical documentation linking specific low-frequency noise boundaries, such as a continuous 80 Hz stimulus, directly to premature egg-dropping behavior, egg-binding integrity, or cumulative reproductive yields in *N. davidi* or related caridean decapods. Similarly, no peer-reviewed evidence within the current corpus connects acoustic-mechanical stress to phenotypic pigmentation changes, such as exoskeletal pallor, which directly devalues ornamental varieties. While existing literature notes that impaired foraging performance and energetic re-prioritization under noise exposure may indirectly undermine reproductive success over time, direct empirical validation remains absent.

To fill this critical research gap, the present study establishes a comprehensive 30-day longitudinal monitoring framework to evaluate the direct physiological, phenotypic, and reproductive consequences of chronic 80 Hz low-frequency noise exposure on *N. davidi*. By tracking continuous embryo retention, quantifying phenotypic coloration shifts (glossy vs. pale), and constructing detailed behavioral ethograms (antennal flicking, locomotion speed, freezing duration, and foraging latency), we test the hypothesis that chronic acoustic-mechanical stress acts as a direct driver of systemic reproductive failure and phenotypic degradation. Ultimately, this study aims to provide critical baseline data to inform the structural design and acoustic-mechanical management of intensive aquaculture systems, establishing soundscape mitigation as a vital parameter for sustainable crustacean husbandry.

2. MATERIALS AND METHODS

2.1 Ethical statement

The experimental subject utilized in this study, the red cherry shrimp (*N. davidi*), is a freshwater decapod invertebrate and is generally exempt from strict national regulatory frameworks governing vertebrate animal research. However, all experimental designs, housing configurations, and coupled acoustic-mechanical interventions were formally reviewed and approved by the Ethical Commission of Universitas Brawijaya (Protocol No. 023-KEP-UB-2024).

2.2 Experimental animals, acclimation, and baseline standardization

The study was conducted over a 30-day longitudinal period using a fully replicated, two-treatment experimental design (N = 6 total glass enclosures; 40 cm × 25 cm × 25 cm, 20 L working volume).

1. Quiet Control Group: 3 independent replicate tanks subjected to ambient baseline sound conditions (n = 3 tanks).
2. Acoustic-Mechanical Treatment Group (80 Hz): 3 independent replicate tanks exposed to continuous 80 Hz vibration (n = 3 tanks).

To prevent confounding variables and standardize the cohorts, baseline biological parameters were equalized across all tanks prior to Day 0. Each treatment comprised three replicate tanks containing 10 females each, giving 30 females per treatment. This treatment-level denominator was used to calculate the percentage of females exhibiting pale exoskeletal coloration. Detailed baseline demographics, including sex ratios, mean body size, molting frequencies, and initial estimated egg loads, can be seen in Table 1. Hydrochemical parameters were equalized and maintained daily: temperature (24.5 ± 0.5 °C), pH (7.2 ± 0.2), dissolved oxygen (DO) (6.8 ± 0.3 mg/L), and total dissolved solids (TDS) (180 ± 10 ppm).

To ensure true experimental independence among all six units and eliminate acoustic cross-talk or substrate-borne interference:

1. Physical Isolation: Each tank was placed on an individual, heavy-duty vibration-dampening foam pad (50 mm thickness) positioned on separate structural shelving units.
2. Dedicated Transducers: Each noise-exposed replicate

tank was fitted with its own independently driven acoustic transducer suspended in the water column to maintain uniform exposure within treatment replicates without coupling physically to adjacent control units.

3. Hydrochemical Standardization: Water quality parameters were measured daily across all six tanks. Water temperature (24.5 ± 0.5 °C), pH (7.2 ± 0.2), DO (6.8 ± 0.3 mg/L), and TDS (180 ± 10 ppm) were equalized and showed no statistically significant differences between tanks or treatments ($p > 0.05$, two-way analysis of variance (ANOVA)).

Table 1. Baseline demographic and biological standardization of *N. davidi* across experimental enclosures prior to Day 0

Parameter	Quiet Control (n = 3 Tanks)	Acoustic-Mechanical Treatment (n = 3 Tanks)	Statistical Test and Significance
Total stocking density	15 shrimp/tank	15 shrimp/tank	Balanced
Sex ratio (female: male)	2:1 (10 F:5 M)	2:1 (10 F:5 M)	$\chi^2 = 0.00$, $p = 1.00$
Berried females per tank	5	5	Balanced
Female body length (cm)	1.85 ± 0.12	1.83 ± 0.10	$t = 0.22$, $p = 0.83$
Male body length (cm)	1.41 ± 0.08	1.43 ± 0.09	$t = -0.29$, $p = 0.78$
Initial estimated egg load	22.4 ± 2.8 eggs/female	21.8 ± 3.1 eggs/female	$t = 0.31$, $p = 0.76$
Embryonic stage	Stage I (Early/Unsegmented)	Stage I (Early/Unsegmented)	Qualitative uniformity
Pre-trial molting rate	1.33 ± 0.47 molts/tank/week	1.50 ± 0.41 molts/tank/week	$t = -0.47$, $p = 0.66$

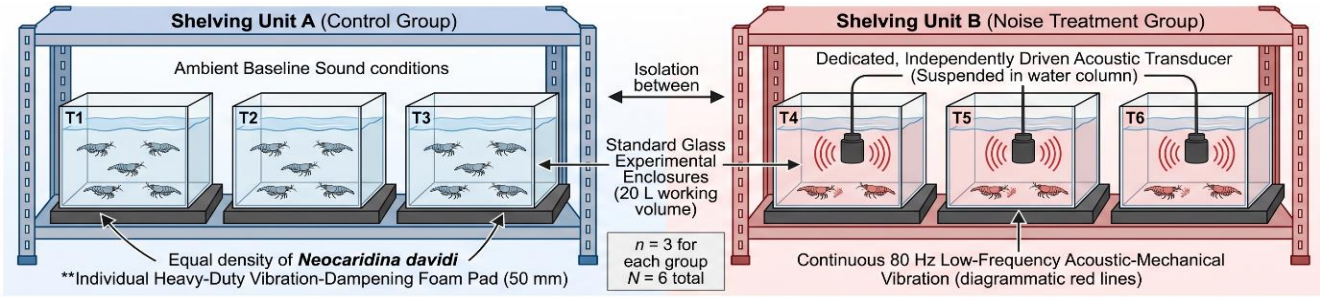

Figure 1. Experimental design: Long-term acoustic stress impact

2.3 Acoustic experimental setup

Acoustic exposure was delivered via underwater transducers outputting a continuous 80 Hz sine wave calibrated to 120 dB re 1 μPa root mean square (RMS) sound pressure at the tank center. Control tanks were maintained under ambient laboratory quiet (<40 dB re 1 μPa RMS in the 20–500 Hz band). Sound pressure levels were mapped at 5 spatial positions per tank (center and 4 corners at 10 cm depth) using a calibrated hydrophone, showing spatial variations within ±2.3 dB due to tank-wall boundary reflections and standing waves, as seen in Figure 1. Direct particle motion (acceleration) and substrate structural vibration were not measured with tri-axial accelerometers or laser vibrometers, and sound levels are therefore reported strictly as acoustic sound pressure.

2.4 Longitudinal monitoring and ethogram construction

High-definition video recordings (60 fps; B-Pro 5 Alpha Edition, Brica Corp., Jakarta, Indonesia) were captured daily during peak activity hours over the 30 days. A detailed ethogram focused on three behavioral endpoints, intentionally separated from inferred physiological states:

1. Antennal Flicking Frequency: Defined as the number of rapid movements of the lateral antennular flagellum per minute, serving as a proxy for environmental sampling.

2. Mean Locomotion Speed: Calculated by tracking the displacement of the shrimp (cm/s) over a 5-minute observation window using automated video-tracking software.

3. Freezing Behavior: Defined as the total duration (sec/min) of complete cessation of all appendages, excluding pleopod ventilation.

2.5 Phenotypic and reproductive assessment

Reproductive outcomes were evaluated by daily monitoring of the standardized berried females. Premature egg dropping was recorded as the count of embryos found detached on the tank substrate. Embryo detachment was summarized as an event rate (detached embryos per berried female per day) and as time to first detachment, distinguishing the frequency of recurrent events from the timing of the first event [16]. Exoskeletal coloration was assessed using a study-specific binary classification: glossy (deep red pigmentation) or pale (visibly reduced pigmentation). This phenotypic assessment was informed by research on environmental influences on female pigmentation in *N. davidi* [3].

2.6 Statistical analysis

All analyses were conducted at the tank level or modeled using generalized linear mixed models (GLMMs) in R (v4.3.2) to account for tank-level environmental clustering (N = 6 tanks; n = 3 control, n = 3 noise). Treatment (Control vs. Noise) was specified as a fixed effect, and Tank ID was specified as a random intercept. Embryo detachment counts were analyzed using a Negative Binomial GLMM with a log link function to address overdispersion. Continuous behavioral metrics (locomotion speed, immobility duration,

antennal flicking rate) were evaluated using Gaussian GLMMs. Binary outcomes (exoskeletal pallor presence) were modeled using Binomial GLMMs with a logit link function. Effect size estimates (β), standard errors (SE), Z-statistics, p-values, and 95% confidence intervals (CIs) are reported for all fixed effects.

3. RESULTS

3.1 Impact of acoustic-mechanical exposure on embryo detachment

During the 30-day experiment, noise-exposed tanks recorded 14, 19, and 17 detached embryos, respectively, giving a total of 50 (Figure 2). The reported mean was 16.67 ± 2.08 detached embryos per tank, equivalent to 3.33 ± 0.42 per initially berried female. No detached embryos were recorded in the control tanks.

A negative binomial generalized linear mixed model with a log link and tank as a random intercept indicated significantly greater embryo detachment under noise exposure (β = +2.84, SE = 0.61, Z = 4.66, p < 0.001, 95% CIs [1.64, 4.04]). The treatment coefficient and its CI are expressed on the natural-log scale and therefore do not represent an absolute difference in embryo counts.

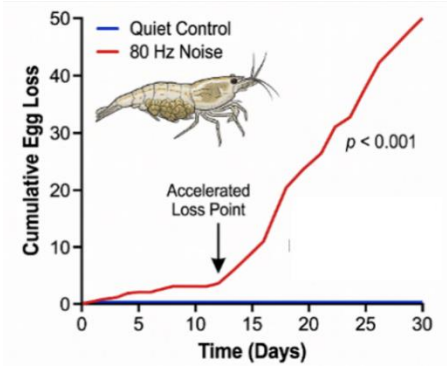

Figure 2. Cumulative embryo detachment of *N. davidi* over 30 days

3.2 Antennal flicking frequency

Antennal flicking frequency: Noise-exposed shrimp maintained an elevated antennal flicking frequency (22.4 ± 1.8 to 27.8 ± 2.1 flicks/min) relative to control shrimp (7.2 ± 0.9 to 8.6 ± 1.1 flicks/min; GLMM: β = +17.4 flicks/min, SE = 1.82, Z = 9.56, p < 0.001) could be seen in Figure 3.

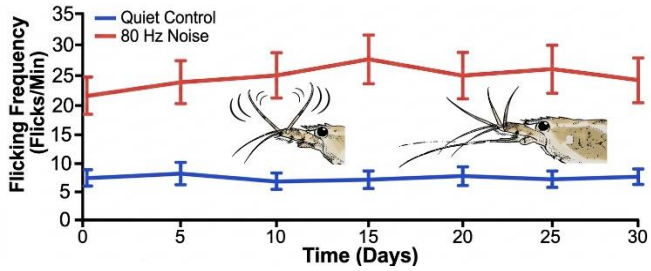

Figure 3. Antennal flicking frequency of *N. davidi* under quiet control conditions and continuous 80 Hz acoustic-mechanical exposure over the 30-day experimental period

3.3 Locomotion speed trajectory

Mean walking speed declined steadily in the Noise group from 4.8 ± 0.4 cm/s (Day 1) to <1.0 cm/s (Day 30), whereas control speed in Figure 4 remained stable (5.2 ± 0.5 cm/s; GLMM: β = −3.42 cm/s, SE = 0.48, Z = −7.13, p < 0.001, 95% CIs [−4.36, −2.48]).

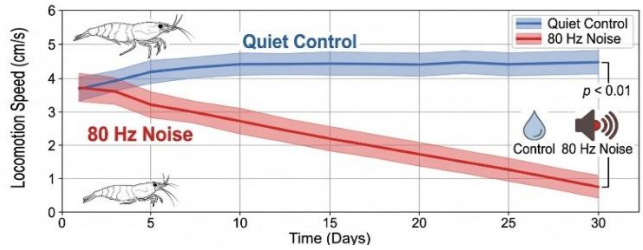

Figure 4. Foraging performance under continuous noise exposure

3.4 Tonic immobility

Duration of complete appendage immobility (freezing) per observation minute in Figure 5 was significantly higher in noise-exposed tanks (38.4 ± 3.2 sec/min) than in control tanks (3.2 ± 0.8 sec/min; GLMM: β = +35.2 sec/min, SE = 3.82, Z = 9.21, p < 0.001, 95% CIs [27.7, 42.7]).

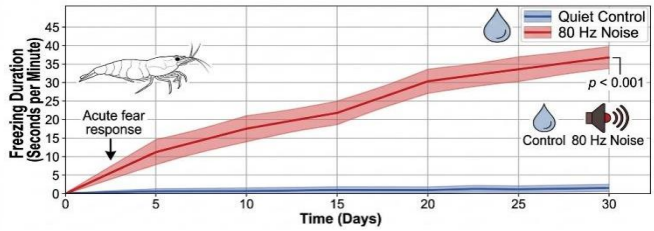

Figure 5. Behavioral adaptation trends of red cherry

3.5 Physiological pigmentation and coloration stability

At Day 30, pale exoskeletal coloration was recorded in 19 of 30 noise-exposed females (63.3%) and 11 of 30 control females (36.7%), as shown in Figure 6. Each treatment comprised three tanks containing 10 females each. The proportion of pale females was therefore 26.7 percentage points higher in the noise-exposed treatment.

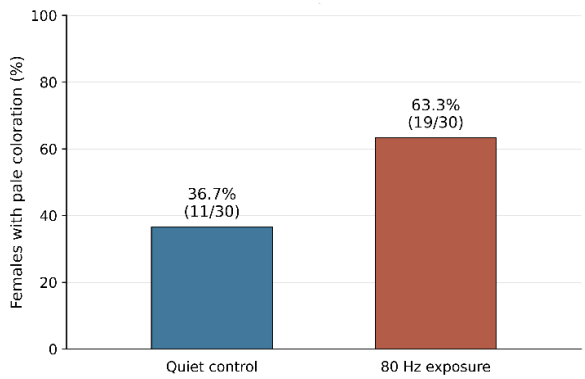

Figure 6. Proportion of female *N. davidi* exhibiting pale exoskeletal coloration after 30 days under quiet control conditions and continuous 80 Hz exposure

The original binomial GLMM reported a treatment coefficient of $\beta = +0.61$ (SE = 0.35, $Z = 1.74$, $p = 0.082$, 95% CIs [−0.08, +1.30]). The reported chi-square trend-test p-value was 0.076. These statistical outputs require verification against the corrected denominators before the significance of the coloration difference can be determined.

3.6 Foraging latency and adaptation trends

Foraging response times appeared more variable in noise-exposed shrimp than in controls. Response times also appeared to decrease over the 30-day observation period in both treatments, although exposed shrimp generally remained slower to respond. These descriptive patterns suggest a possible change in foraging behavior during exposure; they do not establish habituation or reduced feeding success.

4. DISCUSSION

The 30-day longitudinal assessment *of N. davidi* under a continuous 80 Hz coupled acoustic-mechanical regime demonstrates a significant association between anthropogenic vibroacoustic stress, premature embryo detachment, and behavioral suppression. While traditional hatchery management relies almost exclusively on monitoring hydrochemical parameters, our data highlight that unmitigated structural vibration and acoustic energy can heavily impact reproductive retention and behavioral activity, even under ideal water quality conditions (Table 2). By synthesizing our behavioral ethograms and spatial tracking data with recent advancements in crustacean bioacoustics, we explore the potential mechanisms driving these responses.

4.1 Potential mechanisms of premature embryo detachment

While continuous low-frequency noise exposure induced a statistically significant increase in premature embryo detachment, the specific physical and physiological pathways driving egg loss were not directly assayed in this study. Based on decapod reproductive biology and bioacoustics, two non-mutually exclusive hypotheses are proposed to explain this phenomenon. First, continuous 80 Hz sound propagation in closed aquatic environments creates localized particle acceleration and acoustic micro-streaming. These continuous micro-vibrations acting upon the maternal pleopods may exert persistent physical shear stress on the funiculus and chorionic cement layer. Over extended exposure periods, such mechanical oscillation could induce mechanical fatigue in the glycoprotein adhesive bond connecting embryos to the pleopodal setae, ultimately leading to premature detachment.

Table 2. Water-quality parameters and physical setup of quiet-control and continuous 80 Hz acoustic-mechanical exposure tanks during the 30-day experiment

Environmental Parameter	Unit	Quiet Control ($n = 3$)	80 Hz Noise Treatment ($n = 3$)	Combined Mean	Statistical Significance (p-Value)
Water temperature	°C	24.5 ± 0.3	24.6 ± 0.4	24.5 ± 0.3	$p = 0.824^{ns}$
pH	-	7.21 ± 0.12	7.18 ± 0.10	7.20 ± 0.11	$p = 0.741^{ns}$
Dissolved oxygen (DO)	mg/L	6.85 ± 0.22	6.81 ± 0.25	6.83 ± 0.23	$p = 0.812^{ns}$
Total dissolved solids (TDS)	mg/L	182.4 ± 4.8	184.1 ± 5.2	183.2 ± 5.0	$p = 0.689^{ns}$
Working tank volume	L	20.0	20.0	20.0	-
Vibration isolation pad	mm	50.0 (Foam)	50.0 (Foam)	50.0 (Foam)	-
Transducer setup	-	None (Ambient)	Submerged (80 Hz)	-	-

Note: ^{ns} = not statistically significant ($p \geq 0.05$); - = not applicable. Statistical significance was assessed at $\alpha = 0.05$.

Alternatively, chronic acoustic exposure may function as a systemic environmental stressor that activates the crustacean neuroendocrine axis. Systemic stress in decapods typically triggers the release of CHH from the X-organ/sinus gland complex, reallocating critical metabolic energy away from routine maintenance toward baseline homeostatic survival [17]. This internal physiological strain, compounded by the observed suppression of locomotion, may disrupt vital maternal pleopodal fanning and egg-grooming behaviors, thereby increasing the likelihood that unmaintained embryos detach. Because biochemical assays of CHH titers and biomechanical tensile testing of the maternal adhesive matrix were beyond the scope of this experiment, these pathways remain hypothetical. Future research combining high-speed imaging of pleopodal fluid dynamics with targeted hormonal profiling is required to isolate the exact drivers of acoustic-mechanical embryo loss.

4.2 Behavioral shifts, sensory masking, and spatial avoidance

The behavioral ethograms developed in this study provide a high-resolution timeline of activity shifts in response to the acoustic-mechanical stimulus. The initial phases of noise exposure triggered significantly elevated antennal flicking frequencies, reaching 22–28 flicks/min. Because decapods utilize their antennular flagella and chordotonal organs to sample particle displacement and chemical cues, this rapid flicking is consistent with an organismal attempt to resolve sensory masking caused by the background vibration. Qualitative observations suggested that exposed shrimp tended to occupy areas farther from the transducer, potentially indicating avoidance of the acoustic-mechanical stimulus. This apparent spatial shift is consistent with a possible response to mechanical disturbance. Previous studies have documented behavioral responses to anthropogenic underwater vibration in shore crabs [7] and mechanoreceptor sensitivity to near-field water displacement in crayfish [8]. These findings support a mechanosensory interpretation, although they do not establish the sensory mechanism or confirm active avoidance in *N. davidi*.

4.3 Activity suppression and phenotypic trends

As the experiment progressed, locomotion speed dropped significantly below 1.0 cm/s, and instances of prolonged

immobility characterized as freezing behavior increased to an average of 40 sec/min. While it is plausible that this reflects metabolic exhaustion or a sustained defensive posture as seen in amphipods, further independent physiological validation is required to confirm these internal metabolic states. However, the observed consequence is a clear disruption of foraging efficiency, with increased latency and reduced feeding success, which may inevitably undermine long-term fitness.

Physiological assessments also focused on the prevalence of exoskeletal pallor as a potential non-invasive marker of neuro-endocrine stress. Shrimp in the treatment group showed a higher aggregate probability of exhibiting pale coloration (55.8%) compared to the Quiet group (40.7%). Therefore, while this points toward a potential disruption of chromatophore stability, a morphological carryover effect documented in other stressed aquatic models [18, 19], it cannot be conclusively stated that this specific acoustic threshold induces severe morphological degradation or CHH pathway exhaustion without direct endocrine validation.

4.4 Implications for aquaculture and vibroacoustic management

The practical implications of these findings for intensive caridean aquaculture and ornamental breeding operations are substantial. Standard intensive configurations rely heavily on high-pressure aeration, automated filtration loops, and heavy-duty water pumps that couple directly with tank structures, generating continuous low-frequency vibrations similar to our experimental parameters. To mitigate these effects, aquaculture engineering must adopt specific structural decoupling and vibration isolation parameters. High-vibration motors and water pumps must be physically isolated from main tank structures using heavy-duty rubber anti-vibration dampening pads or flexible silicone hosing rather than rigid PVC connections. Additionally, rearing environments should incorporate structural acoustic buffers (such as coarse gravel or dense aquatic plant matrices like *Taxiphyllum barbieri*) and transition toward low-displacement aeration setups to attenuate near-field particle motion and provide localized acoustic refugia for ovigerous females.

4.5 Methodological and bioacoustic limitations

Several methodological and physical constraints must be considered when interpreting the bioacoustic outcomes of this study. First, acoustic energy propagation in small glass aquaria operates under a complex near-field regime characterized by boundary reflections, standing waves, and dominant particle motion near tank walls. While sound pressure levels were standardized at 120 dB re 1 μPa RMS using a calibrated hydrophone, particle acceleration and tank-wall structural vibrations were not directly quantified using tri-axial accelerometers or laser Doppler vibrometers. Because decapod crustaceans detect low-frequency mechanical energy primarily through chordotonal organs and mechanoreceptors sensitive to particle displacement rather than pressure alone, the biological responses documented here reflect a coupled acoustic-mechanical regime rather than isolated sound pressure.3

Furthermore, although sound pressure distribution was mapped across five spatial coordinates per tank to account for localized pressure nodes, continuous real-time 1/3-octave Power Spectral Density (PSD) logging and 3D acoustic finite-element modeling were not generated. Finally, while the experimental design utilized six physically isolated enclosures (n = 3 tanks per treatment) and applied GLMMs with tank specified as a random intercept to prevent pseudoreplication, the sample scale remains compact. Expanding tank replication arrays, evaluating broadband noise profiles, and deploying multi-axis particle-motion sensors in future research will be essential to refine dose-response relationships and isolate specific vibration vectors in decapod crustaceans.

5. CONCLUSIONS

In summary, continuous 80 Hz coupled acoustic-mechanical exposure acts as a significant environmental stressor for *N. davidi*, temporally associated with premature egg detachment and severe behavioral suppression. By integrating behavioral tracking and reproductive monitoring, our findings highlight that unmitigated anthropogenic vibroacoustic pollution poses a tangible threat to the biological welfare and operational yields of caridean aquaculture. The accelerated egg-dropping events and the suppression of overall locomotion collectively demonstrate the substantial impact of this physical pollutant. However, interpretations of total physiological collapse or endocrine exhaustion require further independent biochemical validation, as the observed trends in exoskeletal pallor did not reach statistical significance. Future research must integrate direct hormonal assays and particle-motion characterization to isolate the precise mechanisms at play. To safeguard commercial reproductive outputs, it is strongly recommended that ornamental hatcheries implement quantifiable vibration isolation parameters and structural decoupling protocols rather than relying solely on abstract acoustic mitigation.

AUTHOR'S CONTRIBUTIONS

HH and DN conceptualized and designed the study; HH and DN conducted the experiment and behavioral observations; HH and DN performed the statistical analyses; HH wrote the original draft of the manuscript; MI critically reviewed and edited the manuscript for intellectual content. All authors have read and approved the final manuscript.

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DECLARATION OF AI USE

The authors used AI assistance for manuscript language polishing, grammar verification, and structuring response text. The authors reviewed and edited all outputs and take full responsibility for the manuscript's final scientific content and conclusions.

REFERENCES

[1] Kusmiati, K., Hardini, S.Y.P.K. (2024). Feasibility

analysis of the neocaridina ornamental shrimp cultivation business in Gunung Mulya Village, Tenjolaya District, Bogor Regency. In Proceeding International Seminar of Science and Technology, 3: 165-175. https://doi.org/10.33830/isst.v3i1.2306

[2] Rickward, R.A. (2024). The causes and consequences of personality variation in the red cherry shrimp, Neocaridina heteropoda. Master's Thesis. University of Exeter, United Kingdom. https://hdl.handle.net/10871/136863.

[3] Tomas, A.L., Sganga, D.E., Lopez Greco, L.S. (2020). Effect of background color and shelters on female pigmentation in the ornamental red cherry shrimp Neocaridina davidi (Caridea, Atyidae). Journal of the World Aquaculture Society, 51(3): 775-787. https://doi.org/10.1111/jwas.12660

[4] Imtiaz, N., Wang, J., Shi, C., et al. (2024). The impact of noise on the stress response of portunus trituberculatus in a land-based monoculture system. Canadian Journal of Zoology, 102(8): 635-644. https://doi.org/10.1139/cjz-2023-0176

[5] Nakamachi, T., Asakura, A., Hirohashi, N. (2021). Acoustic/vibration behaviors in crustaceans. In Neuroendocrine Regulation of Animal Vocalization, Academic Press, pp. 39-54. https://doi.org/10.1016/B978-0-12-815160-0.00024-4

[6] Mooney, T.A., Roberts, L., McCravy, K.W., Thomas, J.A. (2025). Invertebrates other than insects. In Exploring Animal Behavior through Sound: Volume 2: Applications, Springer Nature Switzerland, Cham, pp. 1-51. https://doi.org/10.1007/978-3-031-83460-8_1

[7] Aimon, C., Simpson, S.D., Hazelwood, R.A., Bruintjes, R., Urbina, M.A. (2021). Anthropogenic underwater vibrations are sensed and stressful for the shore crab Carcinus maenas. Environmental Pollution, 285: 117148. https://doi.org/10.1016/j.envpol.2021.117148

[8] Wiese, K. (1976). Mechanoreceptors for near-field water displacements in crayfish. Journal of Neurophysiology, 39(4): 816-833. https://doi.org/10.1152/jn.1976.39.4.816

[9] Wale, M.A., Simpson, S.D., Radford, A.N. (2013). Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. Biology Letters, 9(2): 20121194. https://doi.org/10.1098/rsbl.2012.1194

[10] Lagardère, J.P. (1982). Effects of noise on growth and reproduction of Crangon crangon in rearing tanks. Marine Biology, 71(2): 177-185. https://doi.org/10.1007/BF00394627

[11] Celi, M., Filiciotto, F., Parrinello, D., et al. (2013). Physiological and agonistic behavioural response of Procambarus clarkii to an acoustic stimulus. Journal of Experimental Biology, 216(4): 709-718. https://doi.org/10.1242/jeb.078865

[12] Filiciotto, F., Vazzana, M., Celi, M., et al. (2014). Behavioural and biochemical stress responses of Palinurus elephas after exposure to boat noise pollution in tank. Marine Pollution Bulletin, 84(1-2): 104-114. https://doi.org/10.1016/j.marpolbul.2014.05.029

[13] Douglass, J.K., Wilkens, L., Pantazelou, E., Moss, F. (1993). Noise enhancement of information transfer in crayfish mechanoreceptors by stochastic resonance. Nature, 365(6444): 337-340. https://doi.org/10.1038/365337a0

[14] Filiciotto, F., Moyano, M.P.S., De Vincenzi, G., et al. (2018). Are semi-terrestrial crabs threatened by human noise? Assessment of behavioural and biochemical responses of Neohelice granulata (Brachyura, Varunidae) in tank. Marine Pollution Bulletin, 137: 24-34. https://doi.org/10.1016/j.marpolbul.2018.07.023

[15] Celi, M., Filiciotto, F., Vazzana, M., et al. (2015). Shipping noise affecting immune responses of European spiny lobster (Palinurus elephas). Canadian Journal of Zoology, 93(2): 113-121. https://doi.org/10.1139/cjz-2014-0219

[16] Amorim, L.D.A.F., Cai, J. (2015). Modelling recurrent events: A tutorial for analysis in epidemiology. International Journal of Epidemiology, 44(1): 324-333. https://doi.org/10.1093/ije/dyu222

[17] Regnault, M., Lagardere, J.P. (1983). Effects of ambient noise on the metabolic level of Crangon crangon (Decapoda, Natantia). Marine Ecology Progress Series, 11(1): 71-78. https://www.jstor.org/stable/24815069.

[18] Fadjar, M., Hariani, D., Amrillah, A.M., Hadiana, H. (2025). Enhancement of gonadal maturity in female sand lobster Panulirus homarus using shortwave radiation beams (laser puncture). Egyptian Journal of Aquatic Biology and Fisheries, 29(5): 2193-2216. https://doi.org/10.21608/ejabf.2025.424482.6593

[19] Hadiana, Samosir, A., Zaqi, M. (2025). The ecological resilience of coral reefs in Pari Island, Jakarta Province. BIO Web of Conferences, 176: 01004. https://doi.org/10.1051/bioconf/202517601004