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Influence of the lunar cycle on the activity pattern of the high Andean freshwater crab *Neostrengeria macropa*

Influencia del ciclo lunar en el patrón de actividad del cangrejo de agua dulce altoandino *Neostrengeria macropa*

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Abstract

The influence of lunar cycles on animal behavior has been widely documented in marine and terrestrial ecosystems; however, its role in freshwater crustaceans remains poorly understood. This study evaluated the effect of lunar phases on the nocturnal activity pattern of the high Andean freshwater crab *Neostrengeria macropa* (Milne-Edwards, 1853), an endemic species of the Bogotá plateau. Field observations were conducted at the San Rafael Reservoir (La Calera, Cundinamarca, Colombia) over a one-year period, covering all lunar phases. Behavioral activity was recorded continuously during 24-hour sampling periods using focal animal observations, supported by photographic and video records. Crab activity was quantified based on the number of active individuals and movement-related behaviors. Differences among lunar phases were analyzed using circular statistics, including circular histograms, one-way ANOVA, Kruskal–Wallis tests, Watson–Williams tests, and circular analysis of variance. Results revealed a significant effect of lunar phase on crab activity, with the highest activity levels occurring during the crescent moon, followed by the full moon, while waning and new moon phases exhibited lower activity. Pairwise comparisons confirmed significant differences primarily between the crescent moon and both waning and new moon phases. These findings demonstrate that lunar cycles significantly modulate the nocturnal activity of *N. macropa*, suggesting that lunar illumination and associated environmental cues play an important role in shaping behavioral rhythms in freshwater crabs. This study provides novel field-based evidence of lunar-driven activity patterns in a Neotropical high-Andean freshwater crab and contributes to a broader understanding of behavioral ecology in non-marine crustaceans.

Keywords: Pseudothelphusidae, freshwater crab, lunar phases, behavior, Andean region.

Resumen

La influencia del ciclo lunar sobre el comportamiento animal ha sido ampliamente documentada en ecosistemas marinos y terrestres; sin embargo, su efecto en crustáceos de

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agua dulce sigue siendo poco conocido. Este estudio evaluó la influencia de las fases lunares en el patrón de actividad nocturna del cangrejo de agua dulce altoandino *Neostrengeria macropa* (Milne-Edwards, 1853), especie endémica del altiplano de Bogotá. Las observaciones de campo se realizaron en el embalse San Rafael (La Calera, Cundinamarca, Colombia) durante un año completo, abarcando todas las fases lunares. La actividad conductual se registró de manera continua durante periodos de muestreo de 24 horas mediante observaciones focales, apoyadas con registros fotográficos y de video. La actividad de los cangrejos se cuantificó con base en el número de individuos activos y comportamientos asociados al movimiento. Las diferencias entre fases lunares se analizaron mediante estadísticas circulares, incluyendo histogramas circulares, ANOVA de una vía, pruebas de Kruskal–Wallis, Watson–Williams y análisis de varianza circular. Los resultados evidenciaron un efecto significativo de la fase lunar sobre la actividad del cangrejo, registrándose los mayores niveles de actividad durante la luna creciente, seguida por la luna llena, mientras que las fases menguante y luna nueva presentaron menor actividad. Las comparaciones pareadas confirmaron diferencias significativas principalmente entre la luna creciente y las fases menguante y luna nueva. Estos hallazgos demuestran que el ciclo lunar modula significativamente la actividad nocturna de *N. macropa*, sugiriendo que la iluminación lunar y otros estímulos ambientales asociados influyen en sus ritmos conductuales. Este estudio aporta evidencia de campo novedosa sobre la influencia lunar en un crustáceo dulceacuícola altoandino y amplía el conocimiento sobre la ecología del comportamiento en crustáceos no marinos.

Palabras clave: Pseudothelphusidae, braquiuro de agua dulce, fases lunares, comportamiento, región andina.

Introduction

A well-known phenomenon is the influence that the Moon has on the Earth due to gravitational forces, especially affecting marine tidal cycles (NASA 2025), (Openstax, 2022). The lunar phases also have an important effect on biological processes and

interactions in terrestrial environments (Sabato *et al*., 2006; Tigar and Osborne, 1999). Anti-predatory and physiological responses may be triggered by lunar phases (e.g., Navarro-Castilla and Barja, 2014); moon luminosity can modulate activity patterns of mammals (e.g., Norris *et al*., 2010) or lunar-related rhythms can influence reproductive cycles (e.g., Brown, 1988). Aquatic animals may use the lunar cycle as a geographical or spatial landmark during migrations, although its effect on reproductive behaviors is well known as well (DeBruyn and Meeuwig 2001; Lopeztegui *et al*., 2011). In marine ecosystems, lunar phases and tides play a fundamental role in regulating surface currents, upwelling events, larval transport, settlement, and recruitment of numerous marine species (Jones and Epifanio, 1995; Mejias et al., 2011; Shanks, 1998; Tankersley et al., 2002). Conversely, freshwater ecosystems experience negligible tidal forcing; nevertheless, lunar phases may influence freshwater organisms through changes in nocturnal light intensity and circalunar biological rhythms. Such effects have been linked to the synchronization of reproductive events, modulation of locomotor activity, habitat use, foraging behavior, and predator-prey interactions, particularly in nocturnal species (Kronfeld-Schor and Dayan, 2003; Naylor, 2010). For example, lunar periodicity has been proposed as an environmental cue affecting the reproductive phenology of amphibians, suggesting that moonlight can influence breeding activity independently of tidal processes (Grant et al., 2013). These findings indicate that, despite the contrasting physical mechanisms operating in marine and freshwater environments, lunar cycles constitute an important ecological signal capable of shaping behavioral and reproductive responses in aquatic organisms.

Multiple investigations have demonstrated the influence of lunar phases on various biological phenomena in crustaceans. Larval abundance and reproductive cycles have been correlated with the lunar cycle in many decapod species (e.g., Criales et al., 2005; Kingsford et al., 2002; Lopeztegui et al., 2011; Paula, 1989). Lunar phases have been shown to influence activity rhythms and orientation in amphipods (Ugolini, 2003; Ugolini et al., 2016) and isopods (Ciofini and Ugolini, 2018); migrations in mysid shrimps

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(Macquart-Moulin and Maycas, 1995) and hermit crabs (Nieves-Rivera and Williams, 2003); and molting cycles in cumaceans (Akiyama and Yamamoto, 2004) and crayfish (Franke and Hoerstgen-Schwark, 2013), among others. These responses are not merely passive reactions to environmental variation but are mediated by endogenous physiological and behavioral mechanisms. Lunar cues, particularly changes in nocturnal illumination and, in marine environments, tidal oscillations, are perceived through sensory pathways and integrated by endogenous biological clocks. These internal timing systems regulate neuroendocrine processes that synchronize locomotor activity, orientation, migration, molting, and reproductive events with predictable lunar periodicity, thereby maximizing survival and reproductive success (de la Iglesia and Hsu, 2010; Naylor, 2010). Regarding primary freshwater crabs, it is known that they are more active at night; although this is a common observation (Chua *et al*., 2014), few formal reports exist on the topic (e.g., Gherardi *et al*., 1988; Okano *et al*., 2003; Williner and Collins, 2002). For pseudothelphusid crabs, several studies have shown the existence of a circadian rhythm that is dependent on two mechanisms that are regulated by light (Miranda-Anaya, 2004; Miranda-Anaya *et al*., 2003). It is hypothesized that in freshwater crabs the pacemakers are not associated with changes in water level, as is the case in coastal species (Miranda-Anaya, 2004).

Although it is clear that freshwater crabs have crepuscular or nocturnal activity patterns (Miranda-Anaya et al., 2003), it is relevant to explore how these rhythms may be influenced by the lunar cycle. *Neostrengeria macropa* (Milne-Edwards, 1853) is an endemic freshwater crab restricted to streams, springs, wetlands, and small rivers of the Bogotá high plateau in the Eastern Cordillera of Colombia (Arias-Pineda et al., 2021; Campos, 1992, 1994; Campos and Rodríguez, 1985). The species inhabits high-Andean freshwater ecosystems that are increasingly threatened by urban expansion, habitat degradation, water pollution, wetland drainage, and hydrological alteration, factors that have contributed to the decline of several freshwater crab populations in Colombia

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(Campos and Lasso, 2015; Cumberlidge et al., 2009; Rivera-Pérez et al., 2022). Consequently, *N. macropa* has been recognized as a species of conservation concern and is currently classified as Vulnerable at the national level (Campos and Lasso, 2015), making it an appropriate model for studies aimed at improving our understanding of its ecology and behavior. Knowledge of the temporal patterns governing its activity may contribute to the design of more effective monitoring protocols, increase detection probability during field surveys, and provide ecological information useful for habitat management and conservation planning (Arias-Pineda et al., 2021; Cumberlidge et al., 2009). Therefore, this study aims to assess the correlation between lunar phases and the activity pattern of the Colombian freshwater crab *Neostrengeria macropa* (Milne-Edwards, 1853), endemic to the high Andean plateau of Bogotá.

Materials and methods

Study area

Field observations were conducted in the San Rafael reservoir located in La Calera, Cundinamarca Department (4°42'14" N, 73°59'35" W), Colombia, at an altitude of 2,700 m above sea level (Figure 1). The reservoir has a capacity of 75 million m3 of water and an area of 371 hectares; it is fed by the Teusacá River (Castro, 2009).

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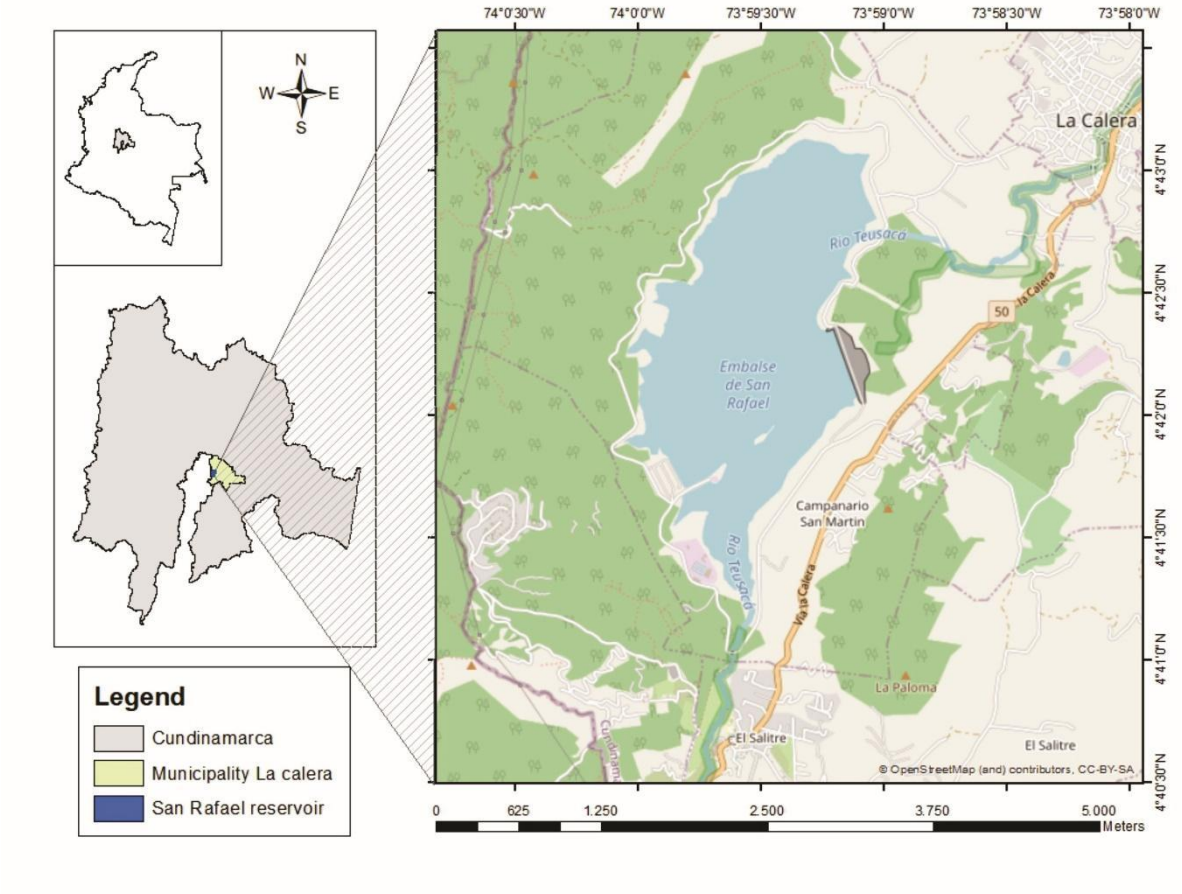


Figure 1. Map of the study area, San Rafael Reservoir, located in La Calera, Cundinamarca Department.

Water temperature ranges between 8° at 10° C. Water quality parameters of the aquatic systems inhabited by the crabs included pH, dissolved oxygen, and other physicochemical variables. Water quality variables were measured in situ using a waterproof Hanna portable multiparameter meter (Hanna Instruments, Woonsocket, RI, USA), which simultaneously recorded pH, oxidation-reduction potential (ORP), electrical conductivity (EC), dissolved oxygen (DO), and turbidity. The measured values were as follows: turbidity (0.48–1.37 units), conductivity (35–39 µS/cm), pH (5.85–6.12), chlorides (3.39–13.68 mg/L), calcium (5–7 mg/L), total hardness (7–14 mg/L), iron (0.02–0.10 mg/L Fe^{2+}), nitrites (0–0.01 µg/L), nitrates (0.17–1.56 mg/L NO_3^-), and dissolved oxygen (6.20–7.20 mg/L).

Field work

Field observations were conducted over 24 h periods starting at 5:00 a.m., for two consecutive days, for each lunar phase (New Moon (NM), First Quarter (FQ), Full Moon (FM), Third Quarter (TQ)), during one year from January 2015 to December the 2015 The lunar phase was verified with the https://www.tutiempo.net/luna/fases-marzo-2015.htm

Observation of the crabs Behaviors

Behavioral observations were conducted using the focal animal sampling method during repeated continuous 24-hour observation sessions over a one-year study period. Sampling was structured around the lunar cycle, with behavioral observations conducted during two consecutive days for each lunar phase (new, waxing, full, and waning moon) every month over a one-year period. This sampling design resulted in 24 observation days for each lunar phase and a total of 96 sampling days, providing comprehensive temporal coverage of lunar variability. Crab activity was quantified based on the number of individuals exhibiting movement, as well as the duration and distance of their displacements. Behavioral activity was quantified by recording movement-related behaviors using predefined activity categories. Individuals were classified according to the extent of their movement during each observation period (e.g., no movement, short-distance movement, moderate-distance movement, and long-distance movement), allowing the frequency of each activity category to be quantified. And hourly records were taken of the number of crabs present within the pool and those actively engaged in activities such as foraging, agonistic interactions (fights or combats), reproduction, molting, and territorial behavior.

To ensure accurate behavioral identification and individual counts, activities were recorded using Sony Alpha 300 digital single-lens reflex (DSLR) cameras (Sony Corporation, Tokyo, Japan). The video recordings were subsequently reviewed for detailed behavioral analyses. Nocturnal observations were conducted using infrared night-vision cameras

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(manufacturer and model), allowing continuous monitoring of crab behavior under low-light conditions without disturbing the animals.

The study area consisted of a delimited pool measuring 24 × 24 m, with a maximum depth of 2 m. The pool was characterized by muddy substrates and clear water, which allowed direct visual observation, and by the presence of macrophytes in both epineustonic and submerged zones. Water temperatures ranged between 8 and 10 °C, and dissolved oxygen levels were high throughout the study period. Observations were conducted by two trained observers.

Statistical analysis

In order to assess if the moon phases had an influence on *N. macropa* abundance, the statistical packages "Circular" of the R software were used Core Team (2013). Shapiro-Wilk and Kolmorogov-Smirnov statistical tests (Lilliefors variation) were used in order to evaluate normality. Homoscedasticity was evaluated by means of a Levene test. Then, a circular histogram was performed to observe differences in the activity of the crabs in the four lunar phases. Once the difference was graphically observed, a one-way ANOVA was used to evaluate whether the mean values differed among the six lunar phases when the assumptions of normality and homogeneity of variances were met. When these assumptions were not satisfied, a Kruskal-Wallis test was applied with the aim of comparing the results of each lunar phase and analyzing the differences in their ranges; for the lunar phases that present differences, the program R generates the word TRUE which means that there are differences, and for those that do not appear in the differences the word FALSE appears. For circular data, the Watson-Williams test was used to compare mean directions among lunar phases.

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Results

Observations were made for a total of 96 days, corresponding to two days for each lunar phase (new, waxing, full, and waning moon) per month over a one-year period. In total, more than 600 *N. macropa* individuals were recorded, assuming no recaptures occurred.

The results obtained from the lunar influence on the activity and behavior of the crab *N. macropa* in the field are presented. It is evident that the species presents a correlation between some lunar phases. During the crescent moon, a greater number of active individuals was recorded[6], followed by the full moon, new moon, and waning moon phases, respectively (Figure 2).

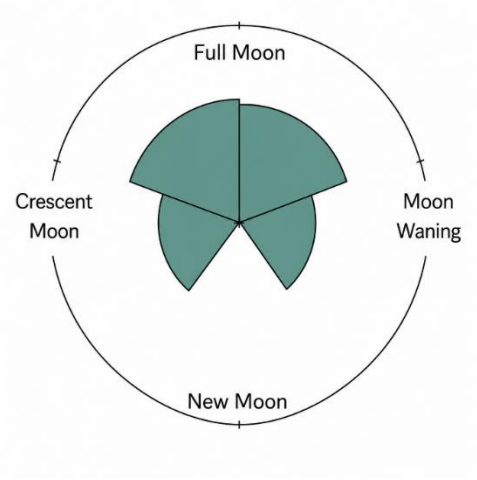


Figure 2. Exploratory circular histogram showing the difference in abundance among different moon phases: C: crescent moon; F: full moon; M: waning moon; N: new moon.

[6] An average of 800 crab observations were recorded throughout the study (it is impossible to know whether sampling and resampling occurred during the study), given that this study did not involve collecting or handling the animals, but only observing their behavior in the field.

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During the exploratory analysis, the ANOVA plot revealed a relationship between the lunar phases and the abundance of N. macropa (Shapiro-Wilk, W=9256, p=0.02962, Kolmogorov-Smirnov (Lilliefors), D = 0.1254, P: 0.2259; Levene Test, Test Statistic = 13.055, P: 1.622e-05) (Figure 3), besides that the results of the Anova support the exploration and that there are differences between the different lunar phases and the abundance of crabs found (Table 1).

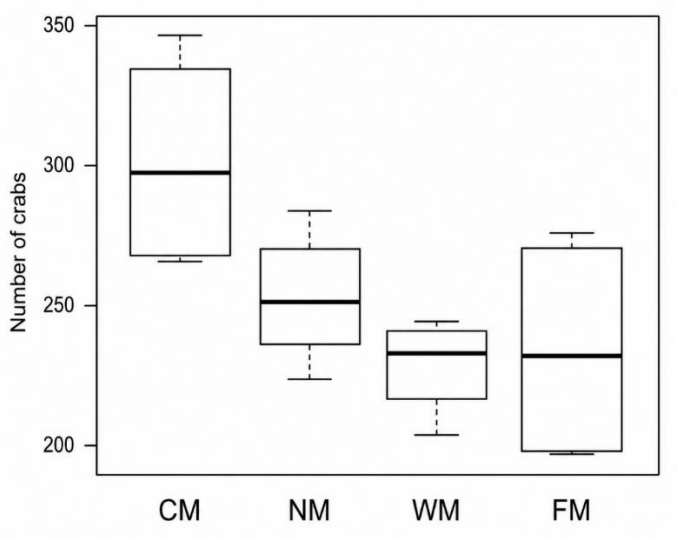


Figure 3. Boxplot showing differences in abundance among the different moon phases: C: crescent moon; F: full moon; M: waning moon; N: new moon.

Table 1. Results of the statistical analyses evaluating differences in activity across lunar phases.

Statistical test

Factor	R-squared	Standard Error	P-value
Lunar Phases	0.4643	—	<0.001
Waxing Moon	—	10.65	<0.001
Full Moon	—	15.06	0.003
New Moon	—	15.06	<0.001
Full Moon	—	15.06	<0.001

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Kruskal wallis	Degrees of freedom	P-value	Chi-square
	3	0.002	14.4515

An analysis of variance (ANOVA) showed a significant effect of lunar phase on activity levels ($R^2 = 0.4643$), with significant differences among individual phases. Non-parametric validation using the Kruskal–Wallis test also revealed significant differences among lunar phases ($\chi^2 = 14.45$, df = 3, $p < 0.01$).

An ANOVA that included the interaction term between factors revealed differences among the lunar phases in the number of active *N. macropa* individuals, with the crescent phase showing the most significant difference (Table 2). To compare each lunar phase in depth and examine these differences, a Kruskal-Wallis test was performed. This test indicated differences between the crescent and waning phases and between the crescent and new phases.

Table 2. Results of the multiple comparisons performed by the Kruskal-Wallis test with the statistical package R with a P value of 0.05.

Moon phases	**Obs.dif**	**Critical.dif**	**Differences**
Crescent – full moon	9.5	12.37452	FALSE
Crescent – waning moon	16.5	12.37452	TRUE
Crescent – new moon	14.0	12.37452	TRUE
Full moon – waning moon	7.0	12.37452	FALSE
Full moon – new moon	4.5	12.37452	FALSE
Waning moon – new moon	2.5	12.37452	FALSE

The Kruskal–Wallis test revealed significant differences in the number of active crabs among lunar phases (Table 2). Pairwise multiple comparisons showed that crab activity during the Crescent Moon differed significantly from both the waning moon (observed

difference = 16.5; critical difference = 12.37) and the new moon (observed difference = 14.0; critical difference = 12.37). No significant differences were detected between the crescent and full moon, full and waning moon, full and new moon, or waning and new moon phases. Finally, the evaluation of lunar phases revealed differences among them, the crescent moon being the one that differs from the rest (Figure 3; Tables 3 and 4).

Table 3. Results of the circular analysis of variance (circular ANOVA) assessing differences in activity across lunar phases.

ACOV	Df	SS	P-value
Between	3	3.281	0.0001933**
Within	28	3.747	
Total	31	7.027	0.0001933**

The analysis revealed a significant effect of lunar phase on activity patterns (F-test, p = 0.00019), with significant variation among groups (between phases) compared to within-phase variation. Degrees of freedom (Df), sum of squares (SS), and associated p-values are reported. Asterisks indicate statistical significance (** $p < 0.01$).

Table 4. Results of pairwise comparisons among lunar phases using the Watson test.

Comparison	Watson Test Statistic	P-value
Crescent vs Full	0.1562	0.10
Crescent vs New	0.6562**	0.001**
Crescent vs Waning	0.8438**	0.0001***
Full vs Waning	0.2031	0.05
Full vs New	0.1562	0.10
Waning vs New	0.3438	0.01

The table shows the Watson test statistic and associated p-values for each comparison. Statistically significant differences in activity patterns between lunar phases are indicated by asterisks ($p < 0.05$*, $p < 0.01$*, **$p < 0.001$).

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All lunar phases were first compared using a circular analysis of variance, which detected significant differences in the angular distribution of crab activity among lunar phases (Table 3). Pairwise Watson–Williams tests were subsequently performed to identify the phases responsible for these differences (Figure 4, A-E). Significant differences were detected between the crescent and new moon phases ($p = 0.001$), the crescent and waning moon phases ($p < 0.001$), and the waning and new moon phases ($p = 0.010$). In contrast, no significant differences were observed between the crescent and full moon ($p = 0.100$) or between the full and new moon ($p = 0.100$). The comparison between the full and waning moon phases showed a marginal result ($p = 0.050$), suggesting a possible shift in the mean direction of activity between these phases.

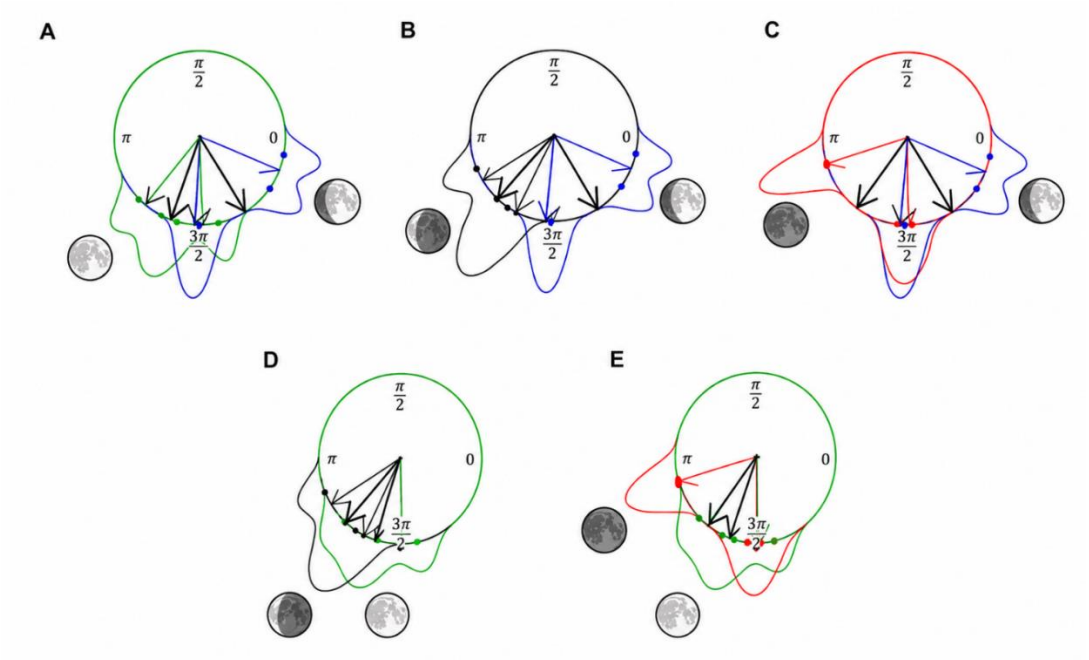


Figure 4. Circular graph and Watson-William test for angular variables. *A.* Lunar phases increasing vs. full P-value of 0.10. *B.* Lunar phases increasing vs. decreasing P-value of 0.001. *C.* Lunar phases increasing vs new P-value of 0.01. *D.* Lunar phases full vs. waning P-value of 0.05. *E.* Lunar phases full vs. new P-value of 0.10.

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Overall, the analyses consistently identified the Crescent Moon as the lunar phase that differed most from the others. The Kruskal–Wallis test showed that crab activity was significantly higher during the crescent moon than during the waning and new moon phases, whereas the circular analysis indicated that the temporal pattern of activity also shifted significantly between these phases.

Discussion

This study observes that a significant portion of *N. macropa* activity occurs during the first quarter and full moon phases, whereas this activity level decreases during the last quarter and new moon phases. However, the scarcity of published research on lunar influence on crustaceans, specifically freshwater crabs of the family Pseudothelphusidae, makes it difficult to compare the study's results, thereby highlighting its novelty and importance.

Williams et al. (1985) reported that the abundance of *Hemigrapsus crassus* and *Mictyris hirtipes* increases at night, particularly during periods of higher wave activity and around the full moon. This is probably due to the greater shelter and security provided by the burrow environment when the water level is higher. We therefore hypothesize that the activity rhythms of both species are regulated by an endogenous mechanism synchronized with the favorable environmental conditions associated with lunar phases.

Another aspect to highlight is the work of Mejias et al (2011), who pointed out that during the full moon and new moon phases, the moon and the sun are aligned with the earth, so that their effects are directly related to the sea producing spring tides. When this happens, the activity of fish and other organisms appears to increase and during the fourth and fourth quarter phases the effects are subtracted, resulting in tides of lesser amplitude generating neap tides, in which the activity of marine organisms decreases. Contrasting the above with the results of the present study, it can be observed that a large part of the number of active

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crabs of *N. macropa* occurs in the lunar phases fourth crescent and full moon and this activity rhythm decreases in waning quarter and new moon.

The observed results suggest that the activity patterns exhibited by freshwater *N. macropa* differ from those commonly reported for marine crustaceans during specific lunar phases. Although the mechanisms underlying these differences remain unclear, they may reflect the distinct environmental conditions and ecological processes operating in freshwater and marine ecosystems. Consequently, further studies on freshwater crustaceans are needed to better understand how lunar cycles influence their behavior and to determine whether these patterns differ consistently from those observed in marine species.

These findings suggest that lunar illumination and/or associated environmental cues play a significant role in modulating the behavioral rhythms of this endemic freshwater crab. Unlike many marine crustaceans, whose activity is closely linked to tidal dynamics, the pattern observed in N. macropa indicates that lunar effects in freshwater systems may operate through distinct mechanisms, possibly related to light intensity, predator avoidance, or endogenous circadian regulation, implying that factors such as urban light pollution could impact the species' natural behavior.

Conclusions

The results of this study demonstrate that the lunar cycle significantly influences the nocturnal activity pattern of the high Andean freshwater crab *Neostrengeria macropa*. Activity levels were not uniformly distributed across lunar phases, with a clear peak during the crescent moon, followed by the full moon, while waning and new moon phases showed reduced activity. Circular and non-parametric statistical analyses consistently supported the existence of significant differences among lunar phases, highlighting the crescent moon as the phase that most strongly differs from the others in terms of crab abundance and activity. This study provides novel field-based evidence of moon-driven behavioral variation in a

Neotropical high-Andean freshwater crab and contributes to a broader understanding of how lunar cycles can determine activity patterns in non-marine crustaceans.

Ethical Statement on the Use of Artificial Intelligence

The paid (Premium) versions of ChatGPT (OpenAI) and Gemini (Google) were used to improve the visual quality of certain images and graphics that had been previously generated using the statistical programs employed in the research, optimizing aspects such as resolution, sharpness, legibility, and presentation. Additionally, these tools, as well as DeepL (free version), were used to perform a linguistic review of the English text, limited to grammatical, spelling, syntactic, and stylistic aspects, with the aim of improving the clarity and fluency of the language.

It is important to expressly note that the writing and the original scientific content of the article were produced by the authors and were not generated by artificial intelligence. Similarly, all data, analyses, results, interpretations, discussion, and conclusions are the original product of the research and analysis conducted by the authors.

References

Akiyama, T. and Yamamoto, M. 2004. Life history of *Nippoleucon hinumensis* (Crustacea: Cumacea: Leuconidae) in Seto Inland Sea of Japan. I. Summer diapause and molt cycle. *Marine Ecology Progress Series*, 284: 211-225. https://doi.org/10.3354/meps284211.

Arcifa, M.S.; da Silva, L.H.S. and da Silva, M.H.L. 1998. The planktonic community in a tropical Brazilian reservoir: Composition, fluctuations and interactions. *Revista*

Brasileira de Biologia, 58(2): 241−254. https://doi.org/10.1127/archiv-hydrobiol/123/1992/479

Arias-Pineda, J. Y., Realpe, E., y González-Rosas, C. 2021. Distribución espacial y aspectos ecológicos de *Neostrengeria macropa* (Decapoda: Pseudothelphusidae) en la sabana de Bogotá, Colombia. *Revista Mexicana de Biodiversidad, 92*, e923438. https://doi.org/10.22201/ib.20078706e.2021.92.3438

Brown, F. M. 1988. Common 30-Day Multiple in Gestation Time of Terrestrial Placentals. *Chronobiology International, 5*(3), 195–210. https://doi.org/10.3109/07420528809079561

Campos, M. R. 1992. New species of fresh-water crabs of the genus *Neostrengeria* Pretzmann, 1965 (Crustacea: Decapoda: Pseudothelphusidae) from Colombia. *Proceedings of the Biological Society of Washington, 105*(3), 540–554.

Campos, M. R. 1994. *Diversidad en Colombia de los cangrejos del género Neostrengeria*. Colección Jorge Álvarez Lleras, No. 5. Academia Colombiana de Ciencias Exactas, Físicas y Naturales. Bogotá, 143 pp.

Campos, M. R. y Rodríguez, G. 1985. A new species of *Neostrengeria* (Crustacea: Decapoda: Pseudothelphusidae) with notes on geographical distribution of the genus. *Proceedings of the Biological Society of Washington, 98*(3), 718–727.

Campos, M. R. y Lasso, C. A. 2015. *Libro rojo de los cangrejos dulceacuícolas de Colombia*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH), Instit uto de Ciencia s Naturales de la Universidad Nacional de Colombia. Bogotá, 168 pp.

DeBruyn, A.M.H. and Meeuwig, J.J. 2001. Detecting lunar cycles in marine ecology: periodic regression versus categorical ANOVA. *Marine Ecology Progress Series,*

214: 307-310. https://doi.org/10.3354/meps214307

De la Iglesia, H.O. and Hsu, Y.W.A. 2010. Biological clocks and rhythms in intertidal crustaceans. *Frontiers in Bioscience*, E2: 1394-1404. https://doi.org/10.2741/E200

Franke, R. and Hoerstgen-Schwark, G. 2013. Lunar-rhythmic molting in laboratory populations of the noble crayfish *Astacus astacus* (Crustacea, Astacidea): an experimental analysis. *PLoS One*, 8: e68653. https://doi.org/10.1371/journal.pone.0068653.

Gherardi, F.; Tarducci, F. and Vannini, M. 1988. Locomotor activity in the freshwater crab *Potamon fluviatile*: the analysis of temporal patterns by radio-telemetry. *Ethology, 77*: 300-316. https://doi.org/10.1111/j.1439-0310.1988.tb00212.x

Grant, R. A., Chadwick, E. A., and Halliday, T. 2013. The lunar cycle: A cue for amphibian reproductive phenology? *Animal Behaviour, 85*, 233–240. https://doi.org/10.1016/j.anbehav.2009.05.007

Jones, M.B. and C.E. Epifanio. 1995. Settlement of brachyuran megalopae in Delaware Bay: an analysis of time series data. *Marine Ecology Progress Series*, 125: 67-76. https://doi.org/10.1111/j.1439-0310.1988.tb00216.x.

Kronfeld-Schor, N. and Dayan, T. 2003. Partitioning of time as an ecological resource. *Annual Review of Ecology, Evolution, and Systematics*, *34*, 153–181. https://doi.org/10.1146/annurev.ecolsys.34.011802.132435

Kingsford, M.J., M. Jeffrey, A.L. Shanks, K.C. Lindeman, S.G. Morgan and J. Pineda. 2002. Sensory environments, larval abilities and local self-recruitment. *Bulletin of Marine Science 70*(1):309-340

Este artículo ha sido sometido al proceso de revisión y aprobación por pares académicos. La versión aquí presentada puede diferir de la versión final.

Lopeztegui, A., Baisre, J.A. y Capetillo, N. 2011. Influencia del ciclo lunar en la captura de langosta espinosa *Panulirus argus* (Decapoda: Palinuridae) en el Golfo de Batabanó, Cuba. *Revista de Biología Tropical, 59*(1): 207-216. https://doi.org/10.15517/rbt.v59i1.3203.

Lowry, M., Williams, D. and Metti, Y. 2007. Lunar landings-Relationship between lunar phase and catch rates for an Australian gamefish-tournament fishery. *Fisheries Research*, 88: 15-23. https://doi.org/10.1016/j.fishres.2007.07.011

Macquart-Moulin, C. and Maycas, E.R. 1995. Inshore and offshore diel migrations in European benthopelagic mysids, genera *Gastrosaccus*, *Anchialina* and *Haplostylus* (Crustacea, Mysidacea). *Journal of Plankton Research*, 17: 531-555. https://doi.org/10.1093/plankt/17.3.531

Mejias, D., Molina, M., Lobo, N. y Contrerar, N. 2011. Ciclo lunar, captura, sexo, peso y talla del cangrejo azul (*Callinectes sapidus*, brachyura, portunidae) en el sur del lago de Maracaibo. Venezuela. Boletín del centro de investigaciones biológicas, 45(3): 325-343. Disponible en: https://www.produccioncientificaluz.org/index.php/boletin/article/view/300

Miranda-Anaya, M. 2004. Circadian locomotor activity in freshwater decapods: an ecological approach. *Biological Rhythm Research, 35*: 69-78. https://doi.org/10.1080/09291010412331313241

Miranda-Anaya, M.; Ramírez-Lomelí, E.; Carmona-Alcoocer, V.P. and Barrera-Mera, B. 2003. Circadian locomotor activity under artificial light in the freshwater crab *Pseudothelphusa americana. Biological Rhythm Research, 34*: 447-458. https://doi.org/10.1076/brhm.34.5.447.27847

National Aeronautics and Space Administration. 2025. *Tides*. NASA Science. Disponible en: https://science.nasa.gov/moon/tides/

Este artículo ha sido sometido al proceso de revisión y aprobación por pares académicos. La versión aquí presentada puede diferir de la versión final.

Navarro-Castilla, A. and Barja, I. 2014. Does predation risk, through monn phase and predator cues, modulate dood intake, antipredatory and physiological responses in wood mice (*Apodemus sylvaticus*)? *Behavioral Ecology and Sociobiology*, 68: 1505-1512. https://doi.org/10.1007/s00265-014-1759-y

Naylor, E. 2010. Chronobiology of Marine Organisms. *Cambridge University Press.* https://doi.org/10.1017/cbo9780511803567

Nieves-Rivera, A.M. and Williams, E.H. 2003. Annual migrations and spawning of *Coenobita clypeatus* (Herbst) on Mona Island (Puerto Rico) and notes on inland crustaceans. *Crustaceana*, 76: 547-558. https://doi.org/10.1163/156854003322316191

Norris, D.; Michalski, F. and Peres, C.A. 2010. Habitat patch size modulates terrestrial mammal activity patterns in Amazonian forest fragments. *Journal of Mammalogy*, 91: 551-560. https://doi.org/10.1644/09-MAMM-A-199.1

Okano, T.; Suzuki, H. and Horie, M. 2003. Habitat use and activity patterns of three Japanese freshwater crabs of the genus *Geothelphusa* (Decapoda, Brachyura, Potamidae). *Journal of Crustacean Biology*, 23: 308-317. https://doi.org/10.1651/0278-0372(2003)023[0308:huaapo]2.0.co;2

OpenStax. 2022. *Astronomy 2e* (Section 4.6: Ocean Tides and the Moon). OpenStax, Rice University. Disponible en: https://openstax.org/books/astronomy-2e/pages/4-6-ocean-tides-and-the-moon

Paula, J. 1989. Rhythms of larval release of decapod crustaceans in the Mira Estuary, Portugal. *Marine Biology*, 100: 309-312. https://doi.org/10.1007/bf00391144

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Dispnible en: http://www.R-

project.org/

Rivera-Pérez, J. M., Llano Arias, C. A. y Guevara, G. 2022. Distribución espacial y conservación de cangrejos de agua dulce (Decapoda: Pseudothelphusidae) en Caldas, Colombia. *Biota Colombiana, 23*(2), e982. https://doi.org/10.21068/2539200X.982

Sábato, M. A. L., Melo, L. F. B. de, Magni, E. M. V., Young, R. J. and Coelho, C. M.. 2006. A note on the effect of the full moon on the activity of wild maned wolves, *Chrysocyon brachyurus*. *Behavioural Processes, 73:* 228-230. https://doi.org/10.1016/j.beproc.2006.05.012

Shanks, A.L. 1998. Abundance of post larval *Callinectes sapidus, Penaeus spp., Uca spp., and Labinia spp*., collected at an outer coastal site and their cross-shelf transport. Marine Ecology Progress Series 168: 57-69. https://doi.org/10.3354/meps

Tankersley, R. A., Welch, J. M. and Forward, R. B. Forward. 2002. Settlement of blue crab (*Callinectes sapidus*) postlarvae during selective tidal-stream transport. *Marine Biology 141*: 863-875. https://doi.org/10.1007/s00227-002-0896-4

Tigar, B. J., and Osborne, P. E. 1999. The influence of the lunar cycle on ground-dwelling invertebrates in the Arabian desert. *Journal of Arid Environments 43*: 171-182. https://doi.org/10.1006/jare.1999.0541

Ugolini, A. 2003. Activity rhythms and orientation in sandhoppers (Crustacea, Amphipoda). *Frontiers in Bioscience*, 8, s722-732M. https://doi.org/10.2741/1041

Ugolini, A., Hoelters, L. S., Ciofini, A., Pasquali, V. y Wilcockson, D. C. 2016. Evidence for discrete solar and lunar orientation mechanisms in the beach amphipod, *Talitrus saltator* Montagu (Crustacea, Amphipoda). *Scientific Reports*, 6: 35575.

https://doi.org/10.1038/srep35575.

Williams, B. G., Naylor, E. and Chatterton, T. D. 1985. The activity patterns of New Zealand mud crabs under field and laboratory conditions. *Journal of Experimental Marine Biology and Ecology, 89*(2–3), 269–282. https://doi.org/10.1016/0022-0981(85)90132-7

Williner, V. and Collins, P.A. 2002. Daily rhythm of feeding activity of the freshwater crab *Dilocarcinus pagei pagei* in the Rio Pilcomayo National Park, Formosa, Argentina. p. 171-178. In: Escobar-Briones, E., Alvarez, F. (eds) *Modern Approaches to the Study of Crustacea*. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-0761-1_27

Yamakawa, T., Matsumiya, Y., Nishimura, M. and Ohnishi, S. 1994. Expanded DeLury's Method with Variable Catchability and its Application to Catch-Effort Data from Spiny Lobster Gillnet Fishery. *Fisheries Science, 60*(1), 59–63. https://doi.org/10.2331/fishsci.60.59

Este artículo ha sido sometido al proceso de revisión y aprobación por pares académicos. La versión aquí presentada puede diferir de la versión final.