Marine Pollution Bulletin 207 (2024) 116917

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Impact of tourism on metal concentrations in *Phorcus sauciatus* due to the COVID-19 pandemic period in Canary Islands (CE Atlantic, Spain)

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ARTICLE INFO

Keywords:
COVID-19
Metal
Trace element
Intertidal

ABSTRACT

The pandemic (COVID-19) had diverse effects on marine pollution. Throughout the lockdown periods, temporary enhancements in water quality and biodiversity were observed due to reduced human activity and constraints on travel and maritime transportation. The marine snail, *Phorcus sauciatus*, served as an indicator for marine pollution, and samples were collected in Tenerife, Canary Islands, during various months in 2020. The findings indicated that metal concentrations in *Phorcus sauciatus* were higher in February but declined in July and December as a result of reduced tourist activity during the pandemic. This underscores the significance of promoting sustainable tourism in the Canary Islands to mitigate high metal concentrations in the marine environment. The COVID-19 pandemic had a positive impact on reducing metal concentrations in marine pollution, underscoring the importance of adopting sustainable tourism practices to protect marine ecosystems.

1. Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, was a global event that began at the end of 2019 in the city of Wuhan, Hubei province, China. Since then, it spread worldwide and has had a significant impact on society, the economy, and public health. (Du et al., 2020; Kumar et al., 2021; Lee, 2020). In order to curb the virus's spread, a range of measures were put into place globally, including practices like social distancing, mask-wearing, frequent handwashing, and the temporary closure of non-essential activities. Moreover, large-scale vaccination campaigns were undertaken to provide immunity to the population against the virus (Castillo-Esparcia et al., 2020; Ciotti et al., 2020; Khanna et al., 2020; Pokhrel and Chhetri, 2021; Suryasa et al., 2021). The COVID-19 pandemic had a dual impact on marine pollution. While the pandemic significantly influenced society and the economy, its effects on marine pollution were intricate and differed from one region to another. On one hand, there were reports of favorable outcomes in specific areas, attributable to reduced human activities and mobility constraints. Throughout lockdowns and reduced travel and maritime transportation, there were transient reductions in marine pollution. In certain locations, improvements in water quality and biodiversity were observed, as there was a decrease in sewage discharge and less plastic contamination (Bashir et al., 2020; Chowdhury et al., 2021; Collins-Kreiner and Ram, 2020; Contini and Costabile, 2020; De-la-Torre and Aragaw, 2021; Du and Wang, 2020; Haryanto, 2020; He et al., 2020; Khanna et al., 2020; López-Bueno et al., 2020; Ntounis et al., 2022; Sicard et al., 2020).

Phorcus sauciatus, this snail has the capacity to act as a bioindicator for marine pollution due to its sensitivity to particular pollutants and shifts in environmental conditions. These snails have close associations with coastal environments, and their presence and population can provide insights into the overall health of the marine ecosystem. Several studies have employed *P. sauciatus* and other snail species as bioindicators to assess water quality and contamination in coastal regions.

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https://doi.org/10.1016/j.marpolbul.2024.116917
Received 7 February 2024; Received in revised form 27 August 2024; Accepted 29 August 2024
Available online 5 September 2024

For example, they have been used to examine heavy metal concentrations in their tissues, which aids in evaluating chemical pollution within these ecosystems. Furthermore, they have been employed to gauge the impacts of organic contamination, such as hydrocarbons, on the marine ecosystem. (Baptista et al., 2021; Bordbar et al., 2015; Boucetta et al., 2019; Boulajfene et al., 2021, 2019; Dhiman and Pant, 2021; Ehlers et al., 2022; Ezraneti, 2021; Lozano-Bilbao et al., 2021; Sousa et al., 2021, 2019, 2018). Therefore, the use of the marine snail species *Phorcus sauciatus* as a bioindicator of marine pollution during the COVID-19 pandemic period is of vital importance to assess how pollution has changed during this time.

2. Material and methods

For this study, 15 samples of Phorcus sauciatus were collected in each of the months of February, July, and December of 2020, the year of the COVID-19 pandemic that began in March. The samples were collected in La Punta de Hidalgo, Tenerife, Canary Islands, Spain (Fig. 1).

2.1. Sampling

The analysis utilized five grams of muscle tissue extracted. To prepare the samples, they were dried for twenty-four hours in an oven set at 70 °C. Following the drying process, the samples were subjected to a muffle furnace at a temperature of 450 °C ± 25 °C until they turned into white ash. These ashes were then filtered and adjusted to a final volume of 25 mL using a 1.5 % HNO3 solution. For the determination of the samples, an analytical technique called Inductively Coupled Plasma Optical Emission Spectrophotometry (ICP-OES) was employed. The ICAP 6300 model (Duo Thermo Scientific, Waltham, MA, USA) with an attached auto sampler (CETAX model ASX-520) was utilized for this purpose (Al, Fe, Cd, Pb, Li and Zn) (Lozano-Bilbao et al., 2022). To ensure the accuracy of the measurements, a quality control solution was employed after every ten samples. Additionally, the accuracy of the analytical procedure was assessed by analyzing internationally recognized standard reference materials, namely DORM-1 and DORM-5, provided by the National Research Council of Canada. The recovery rate achieved with these reference materials exceeded 97 %. To evaluate the performance of the analytical method, blanks and standard reference materials were analyzed alongside the samples. Several validation parameters were verified in this analytical method, including specificity, precision (reproducibility), and accuracy (recovery). These parameters were assessed using the above-mentioned reference materials, each measured ten times under reproducibility conditions. The verification procedure yielded the following results: the method exhibited specificity as there were no spectral interferences observed for the studied metals; precision was confirmed for all metals, with a HORRATR value below 2; and accuracy was established by achieving a recovery rate of over 94 % for all elements studied in the reference material. Thus, the method employed met the criteria for accuracy (recovery), precision (reproducibility), and specificity as specified in EC REGULATION No. 333/2007.

2.2. Statistical analysis

To investigate potential differences in the content and relative composition of heavy metals and trace metals among the samples, a permutational multivariate analysis of variance (PERMANOVA) was conducted using Euclidean distances. The study employed a one-way design with the fixed factor of "date," which had six levels of variation (February, July, and December). The analysis included the following variables: Al, Cd, Cu, Fe, Pb, Li, and Zn. For the analysis, 9999 permutations of interchangeable units were utilized, and post hoc pairwise

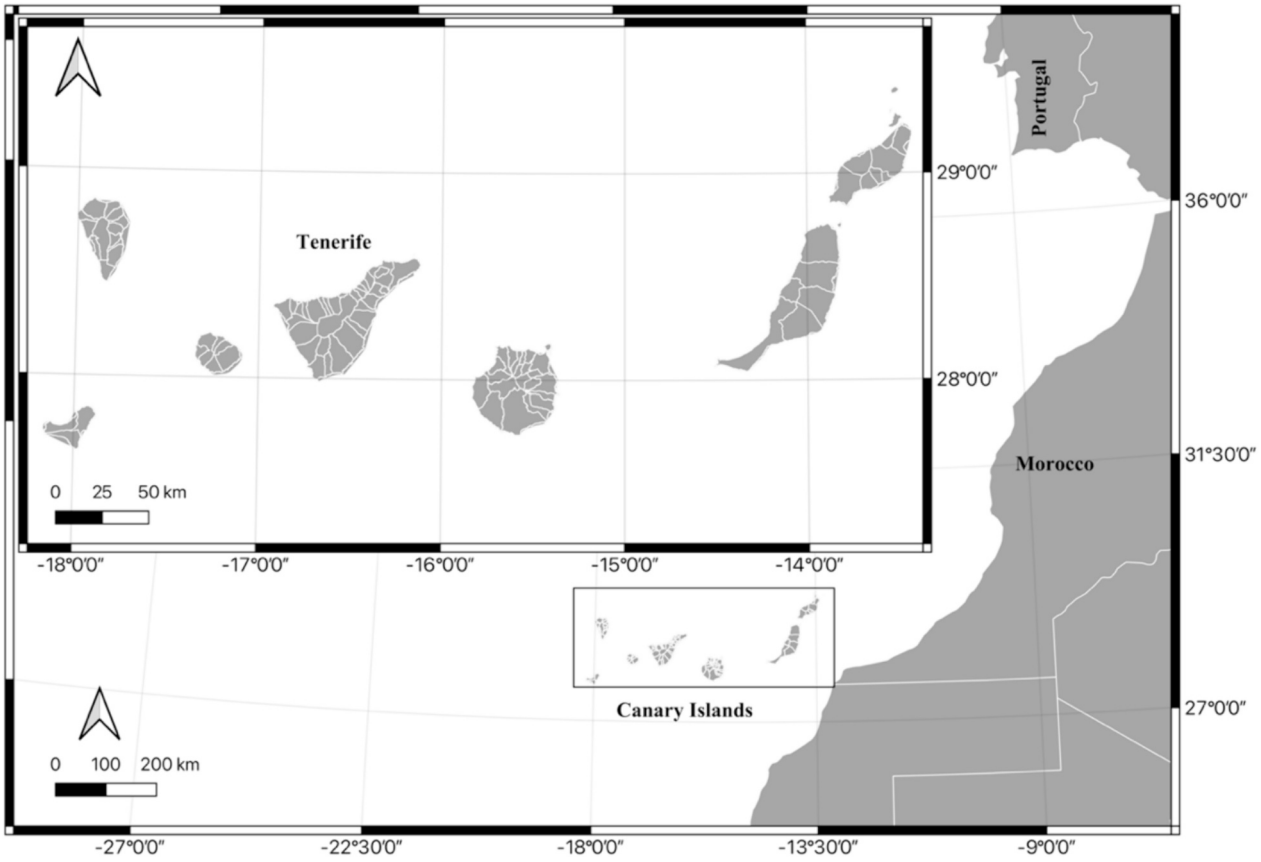

Fig. 1. Sampling area of the anemone *Anemonia sulcata* during the six years of sampling.

comparisons were performed to examine differences between significant factors (p-value <0.05). The statistical packages PRIMER 7 and PERMANOVA þ v.1.0.1 were employed for conducting the analysis (Anderson and Ter Braak, 2003; Anderson, 2004).

3. Results and discussion

Table 1 displays the concentrations of metals and trace elements discovered in *Phorcus sauciatus*. All *P. sauciatus* specimens exhibited an average shell length of 1.9 ± 0.2 cm. Notably, all specimens collected in February exhibited higher concentrations of each of the analyzed metals. In Table 2, we can observe significant disparities between February and the other two months (July and December) for all metals. Conversely, there were no significant variations in metal levels between July and December. These outcomes signify a reduction in metal concentrations immediately following the COVID-19 pandemic. This decrease can be attributed to a significant decline in tourism during this period, as the Spanish government imposed travel restrictions from other countries, leading to the closure of numerous hotels (Castillo-Esparcia et al., 2020; López-Bueno et al., 2020). *P. sauciatus* primarily consumes algal propagules, and algae are known to be substantial accumulators of contaminants. Therefore, they are among the first organisms to accumulate pollution. During this period, there was a significant reduction in the concentrations of heavy metals. As a result, the algal propagules had lower levels of metals and trace elements. Combined with the detoxification mechanisms inherent in mollusks, this led to a sharp decrease in metal concentrations within *P. sauciatus* (Bordbar et al., 2015; Conti and Finoia, 2010; Garnham et al., 1997; Gaur and Rai, 2001; Lozano-Bilbao et al., 2023; Sousa et al., 2018; Yanes et al., 2018; Zeraatkar et al., 2016). It is plausible that, during the pandemic, certain sources of metal pollution, such as industrial emissions and maritime traffic, experienced temporary reductions due to lockdown measures and economic activity restrictions. This, in turn, could have led to a decline in the influx of specific metals into the ocean within particular regions (Ali and Islam, 2020; De-la-Torre and Aragaw, 2021; Rodríguez-Antón and Alonso-Almeida, 2020; Villeneuve and Goldberg, 2020; Wang et al., 2022).

These results highlight the fact that anthropogenic pressure, especially from excessive tourism, significantly impacts marine ecosystems by releasing substantial quantities of compounds into the ocean. Therefore, it is essential for the Canary Islands to adopt sustainable tourism practices. While this may be challenging since the region heavily relies on tourism, the high density of tourists could lead to severe consequences for the ecosystems. Hence, sustainable tourism in the Canary Islands would entail an approach aimed at minimizing environmental impact and maximizing socio-economic benefits for local communities. The Canary Islands, with their rich biodiversity and unique landscapes, are a popular and internationally recognized tourist destination (Baute Díaz et al., 2022; Hernández Sánchez and Oskam, 2022; Mena-Nieto et al., 2021; Passafaro, 2020; Sharpley, 2020).

Table 1
Descriptive data of metal and trace element concentrations in mg/kg.

	Al	Zn	Cd	Pb	Fe	Cu	Li
February							
Mean	63.30	12.68	0.384	0.089	36.99	11.61	15.18
Sd ±	2.11	1.55	0.104	0.016	3.38	1.42	1.51
Min.	60.17	11.15	0.244	0.072	32.40	9.64	13.44
Max.	65.66	15.14	0.567	0.124	41.95	14.19	18.01
July							
Mean	50.78	9.60	0.259	0.068	29.20	9.12	11.99
Sd ±	1.51	0.50	0.029	0.006	2.01	0.85	0.82
Min.	48.87	8.92	0.198	0.058	25.92	7.71	10.91
Max.	52.33	10.18	0.295	0.074	32.07	10.17	13.01
December							
Mean	51.03	9.64	0.262	0.068	29.32	9.13	12.05
Sd ±	2.72	0.48	0.038	0.006	2.13	0.58	1.01
Min.	46.92	8.93	0.190	0.060	25.80	8.10	10.48
Max.	54.95	10.56	0.310	0.075	31.83	9.77	13.40

4. Conclusions

The concentrations of metals and trace elements in *Phorcus sauciatus* were higher in February 2020. Metal concentrations in July and December decreased indirectly due to the COVID-19 pandemic, as the number of tourists on the island decreased. Additionally, the study underscored the crucial role of *P. sauciatus* as a bioindicator for assessing environmental conditions, particularly in coastal areas, owing to its feeding habits and sensitivity to contaminants.

The research also emphasized the significant impact of anthropogenic pressure, primarily stemming from excessive tourism, on marine ecosystems. The release of compounds into the ocean posed a notable threat to these environments. Consequently, the adoption of sustainable tourism practices in the Canary Islands is paramount. Despite the challenges associated with transitioning to sustainable tourism in a region heavily reliant on tourism, it is essential to minimize environmental impact while maximizing socio-economic benefits for local communities. The Canary Islands' unique biodiversity and landscapes contribute to its status as a renowned international tourist destination, further highlighting the urgency of implementing sustainable practices to safeguard these invaluable ecosystems.

In conclusion, sustainable tourism in the Canary Islands is fundamental for mitigating high metal concentrations found in the region and working toward their reduction.

Ethical approval

We confrmed that this manuscript has not been published elsewhere and is not under consideration by another journal. Ethical approval and Informed consent do not applicable for this study.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

CRediT authorship contribution statement

Enrique Lozano-Bilbao: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Arturo Hardisson:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition. **Dailos González-Weller:** Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation. **Soraya Paz:** Writing – review & editing, Writing – original draft, Validation, Software, Resources, Methodology, Investigation, Formal analysis. **Ángel J. Gutiérrez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Investigation, Funding acquisition, Formal analysis.

Declaration of competing interest

All authors declare that the use of animals for this research complies with the requirements of European legislation on the use of animals for experimentation. All anemone samples have been taken with fishing permits and permission from the Spanish ministry. Samples were

Table 2
Pairwise data.

Groups	Al	Zn	Cd	Pb	Fe	Cu	Li
February. July	0.002*	0.002*	0.003*	0.001*	0.001*	0.003*	0.001*
February. December	0.001*	0.001*	0.005*	0.002*	0.001*	0.003*	0.001*
July. December	0.824	0.811	0.931	0.932	0.743	0.814	0.906

obtained from broodstock captured, so these organisms were not slaughtered by the authors of this manuscript, therefore we faithfully comply with the Code of Practice for Housing and Care of Animals Used in Scientific Procedures.

Data availability

Data will be made available on request.

Acknowledgments

Enrique Lozano-Bilbao thanks the University of La Laguna (ULL) and the Spanish Ministry of Universities for the Margarita Salas postdoctoral fellowship, granted by the UNI/551/2021 Order and funded by Next Generation EU Fund.

References

Ali, N., Islam, F., 2020. The effects of air pollution on COVID-19 infection and mortality—a review on recent evidence. Front. Public Health 8, 580057.
Anderson, M.R., 2004. The Resource for the Power Industry Professional. Proceedings of ASME POWER, p. 32.
Anderson, M., Ter Braak, C., 2003. Permutation tests for multi-factorial analysis of variance. J. Stat. Comput. Simul. 73, 85–113. https://doi.org/10.1080/00949650215733.
Baptista, L., Santos, A.M., Melo, C.S., Rebelo, A.C., Madeira, P., Cordeiro, R., Botelho, A. Z., Hipólito, A., Pombo, J., Voelker, A.H.L., 2021. Untangling the origin of the newcomer Phorcus sauciatus (Mollusca: Gastropoda) in a remote Atlantic archipelago. Mar. Biol. 168, 1–16.
Bashir, M.F., Benghoul, M., Numan, U., Shakoor, A., Komal, B., Bashir, M.A., Bashir, M., Tan, D., 2020. Environmental pollution and COVID-19 outbreak: insights from Germany. Air Qual. Atmos. Health 13, 1385–1394.
Baute Díaz, N., Simancas Cruz, M.R., Padrón Fumero, N., Herrera Priano, F.Á., Rodríguez González, P., Gutiérrez Taño, D., Santana Turégano, M.A., Guerra Lombardi, V., García Altmann, S., García González, S., 2022. Tourism Observatory of the Canary Islands. Canary Islands Tourism Sustainability. Progress Report 2022.
Bordbar, L., Dassenakis, M., Catsiki, V.A., Megalofonou, P., 2015. Influence of a ferronickel smelting plant activity on the coastal zone through investigation of metal bioaccumulation on two gastropod species (Patella caerulea and Phorcus turbinatus). J. Environ. Anal. Toxicol. 1.
Boucetta, S., Benchalel, W., Ferroudj, S., Bouslama, Z., Elmsellem, H., 2019. Trace metal biomonitoring of algae (Ulva lactuca), and mollusks (Patella caerulea; Stramonita haemastoma; Phorcus turbinatus) along the Eastarn-Algerian coast. Morrocan J. Chem. 7, 3–7.
Boulajfene, W., Strogyloudi, E., Lasram, M., El Mlayah, A., Vassiliki-Angelique, C., Zouari-Tlig, S., 2019. Biological and biochemical assessment in Phorcus articulatus (Lamarck 1822): contamination and seasonal effect. Environ. Monit. Assess. 191, 1–16.
Boulajfene, W., Lasram, M., Zouari-Tlig, S., 2021. Integrated biomarker response for environmental assessment using the gastropod Phorcus turbinatus along the northern and the northeastern coasts of Tunisia. Life 11, 529.
Castillo-Esparcia, A., Fernández-Souto, A.-B., Puentes-Rivera, I., 2020. Comunicación política y Covid-19. Estrategias del Gobierno de España//Political communication and Covid-19: strategies of the Government of Spain. Profesional de la información, p. 29.
Chowdhury, H., Chowdhury, T., Sait, S.M., 2021. Estimating marine plastic pollution from COVID-19 face masks in coastal regions. Mar. Pollut. Bull. 168, 112419.
Ciotti, M., Ciccozzi, M., Terrinoni, A., Jiang, W.-C., Wang, C.-B., Bernardini, S., 2020. The COVID-19 pandemic. Crit. Rev. Clin. Lab. Sci. 57, 365–388.
Collins-Kreiner, N., Ram, Y., 2020. National tourism strategies during the Covid-19 pandemic. Ann. Tour. Res.
Conti, M.E., Finoia, M.G., 2010. Metals in molluscs and algae: a north–South Tyrrhenian Sea baseline. J. Hazard. Mater. 181, 388–392. https://doi.org/10.1016/j.jhazmat.2010.05.022.
Contini, D., Costabile, F., 2020. Does air pollution influence COVID-19 outbreaks? Atmosphere (Basel).
De-la-Torre, G.E., Aragaw, T.A., 2021. What we need to know about PPE associated with the COVID-19 pandemic in the marine environment. Mar. Pollut. Bull. 163, 111879.
Dhiman, V., Pant, D., 2021. Environmental biomonitoring by snails. Biomarkers 26, 221–239.
Du, W., Wang, G., 2020. Indoor air pollution was nonnegligible during COVID-19 lockdown. Aerosol Air Qual. Res. 20, 1851–1855.
Du, Z., Wang, L., Cauchemez, S., Xu, X., Wang, X., Cowling, B.J., Meyers, L.A., 2020. Risk for transportation of coronavirus disease from Wuhan to other cities in China. Emerg. Infect. Dis. 26, 1049.
Ehlers, S.M., Ellrich, J.A., Koop, J.H.E., 2022. Microplastic load and polymer type composition in European rocky intertidal snails: consistency across locations, wave exposure and years. Environ. Pollut. 292, 118280.
Ezraneti, R., 2021. Littoraria spp. snail (Mollusca: Gastropoda) as a bioindicator in the mangrove ecosystem. In: IOP Conference Series: Earth and Environmental Science. IOP Publishing (p. 012008).
Garnham, G.W., Wase, J., Forster, C., 1997. The use of algae as metal biosorbents. In: Biosorbents for metal ions, 11, p. 37.
Gaur, J.P., Rai, L.C., 2001. Heavy metal tolerance in algae. In: Algal Adaptation to Environmental Stresses. Springer, pp. 363–388.
Haryanto, T., 2020. COVID-19 pandemic and international tourism demand. J. Dev. Econ. 5, 1–5.
He, G., Pan, Y., Tanaka, T., 2020. COVID-19, City Lockdowns, and Air Pollution: Evidence From China. MedRxiv, pp. 2003–2020.
Hernández Sánchez, N., Oskam, J., 2022. A "new tourism cycle" on the Canary Islands: scenarios for digital transformation and resilience of small and medium tourism enterprises. J. Tour. Fut.
Khanna, R.C., Cicinelli, M.V., Gilbert, S.S., Honavar, S.G., Murthy, G.V.S., 2020. COVID-19 pandemic: lessons learned and future directions. Indian J. Ophthalmol. 68, 703–710.
Kumar, A., Singh, R., Kaur, J., Pandey, S., Sharma, V., Thakur, L., Sati, S., Mani, S., Asthana, S., Sharma, T.K., 2021. Wuhan to world: the COVID-19 pandemic. Front. Cell. Infect. Microbiol. 242.
Lee, A., 2020. Wuhan novel coronavirus (COVID-19): why global control is challenging? Public Health 179, A1.
López-Bueno, R., Calatayud, J., Casaña, J., Casajús, J.A., Smith, L., Tully, M.A., Andersen, L.L., López-Sánchez, G.F., 2020. COVID-19 confinement and health risk behaviors in Spain. Front. Psychol. 11, 1426.
Lozano-Bilbao, E., Herranz, I., González-Lorenzo, G., Lozano, G., Hardisson, A., Rubio, C., González-Weller, D., Paz, S., Gutiérrez, Á.J., 2021. Limpets as bioindicators of element pollution in the coasts of Tenerife (Canary Islands). Environ. Sci. Pollut. Res. https://doi.org/10.1007/s11356-021-15212-7.
Lozano-Bilbao, E., Lozano, G., Gutiérrez, Á.J., Hardisson, A., Rubio, C., Paz, S., Weller, D. G., 2022. The influence of the degassing phase of the Tagoro submarine volcano (Canary Islands) on the metal content of three species of cephalopods. Mar. Pollut. Bull. 182, 113964 https://doi.org/10.1016/j.marpolbul.2022.113964.
Lozano-Bilbao, E., Hernández, J.C., Paz, S., Hardisson, A., Rubio, C., González-Weller, D., Gutiérrez, Á.J., 2023. Structuring algae as buffers for heavy metals and trace elements in the Canary Islands intertidal habitat. Mar. Pollut. Bull. 190, 114890.
Mena-Nieto, A., Estay-Ossandon, C., Dos Santos, S.P., 2021. Will the Balearics and the Canary Islands meet the European Union targets for municipal waste? A comparative study from 2000 to 2035. Sci. Total Environ. 783, 147081.
Ntounis, N., Parker, C., Skinner, H., Steadman, C., Warnaby, G., 2022. Tourism and hospitality industry resilience during the Covid-19 pandemic: evidence from England. Curr. Issue Tour. 25, 46–59.
Passafaro, P., 2020. Attitudes and tourists' sustainable behavior: an overview of the literature and discussion of some theoretical and methodological issues. J. Travel Res. 59, 579–601.
Pokhrel, S., Chhetri, R., 2021. A literature review on impact of COVID-19 pandemic on teaching and learning. High. Educ. Futur. 8, 133–141.
Rodríguez-Antón, J.M., Alonso-Almeida, M. del M., 2020. COVID-19 impacts and recovery strategies: the case of the hospitality industry in Spain. Sustainability 12, 8599.
Sharpley, R., 2020. Tourism, sustainable development and the theoretical divide: 20 years on. J. Sustain. Tour. 28, 1932–1946.
Sicard, P., De Marco, A., Agathokleous, E., Feng, Z., Xu, X., Paoletti, E., Rodriguez, J.J.D., Calatayud, V., 2020. Amplified ozone pollution in cities during the COVID-19 lockdown. Sci. Total Environ. 735, 139542.
Sousa, R., Delgado, J., González, J.A., Freitas, M., Henriques, P., 2018. Marine snails of the genus Phorcus: biology and ecology of sentinel species for human impacts on the rocky shores. Biol. Resour. Water 2018, 141–167.
Sousa, R., Vasconcelos, J., Delgado, J., Riera, R., González, J.A., Freitas, M., Henriques, P., 2019. Filling biological information gaps of the marine topshell Phorcus sauciatus (Gastropoda: Trochidae) to ensure its sustainable exploitation. J. Mar. Biol. Assoc. U. K. 99, 841–849.
Sousa, R., Vasconcelos, J., Vera-Escalona, I., Delgado, J., Freitas, M., González, J.A., Riera, R., 2021. Major Ocean currents may shape the microbiome of the topshell Phorcus sauciatus in the NE Atlantic Ocean. Sci. Rep. 11, 12480.
Suryasa, I.W., Rodríguez-Gámez, M., Koldoris, T., 2021. The COVID-19 pandemic. Int. J. Health Sci. 5.

Villeneuve, P.J., Goldberg, M.S., 2020. Methodological considerations for epidemiological studies of air pollution and the SARS and COVID-19 coronavirus outbreaks. Environ. Health Perspect. 128, 95001.
Wang, Q., Zhang, M., Li, R., Jiang, X., 2022. Does marine environmental research meet the challenges of marine pollution induced by the COVID-19 pandemic? Comparison analysis before and during the pandemic based on bibliometrics. Mar. Pollut. Bull. 183, 114046.
Yanes, Y., Hutterer, R., Linstädter, J., 2018. On the transition from hunting-gathering to food production in NE Morocco as inferred from archeological Phorcus turbinatus shells. Holocene 28, 1301–1312.
Zeraatkar, A.K., Ahmadzadeh, H., Talebi, A.F., Moheimani, N.R., McHenry, M.P., 2016. Potential use of algae for heavy metal bioremediation, a critical review. J. Environ. Manage. 181, 817–831.