Aqua Publisher®

International Journal of Marine Science, 2024, Vol.14, No.6, 341-349
http://www.aquapublisher.com/index.php/ijms

Research Article **Open Acce**

Urban Marine Biodiversity Monitoring by Environmental Science Students

Fernando Condal Domingo

Rambla Prim Institute (Department of Environment; IRP) C/ de Cristóbal de Moura, 223, 08019 Barcelona, Spain

Corresponding email: fernandocondal@gmail.com

International Journal of Marine Science, 2024, Vol.14, No.6, doi: 10.5376/ijms.2024.14.0038

Received: 17 Oct., 2024

Accepted: 08 Nov., 2024

Published: 10 Dec., 2024

Preferred citation for this article:

Condal F., 2024, Urban marine biodiversity monitoring by environmental science students, International Journal of Marine Science, 14(6): 341-349 (doi: 10.5376/ijms.2024.14.0038)

Abstract Urban marine environments face unique ecological challenges under anthropogenic pressures. This five-year biodiversity monitoring project conducted at three urban beaches in Barcelona (Spain) evaluated species diversity, abundance, and ecosystem resilience using systematic snorkelling surveys. A total of 38 species were identified (γH'), with notable post-COVID increases in the Shannon biodiversity index (αH'), peaking in 2022 (2.66). Key species, such as *Diplodus sargus* and *Oblada melanura*, dominated rocky habitats at Espigó de Sant Sebastià and Espigó de Sant Miquel, while distinct assemblages characterized Espigó and Banys del Fòrum. The presence of artificial barriers and nutrient inflows from the Besòs River further shaped biodiversity dynamics. The study also highlighted the transformative educational benefits of involving students in hands-on research, fostering technical skills and environmental stewardship. These findings emphasize the importance of targeted conservation strategies and continuous monitoring to safeguard urban marine ecosystems.

Keywords Urban marine biodiversity; Eenvironmental monitoring; Snorkelling surveys; Species abundance; Shannon biodiversity index; Barcelona beaches; Marine conservation

1 Introduction

Biodiversity monitoring in urban coastal areas has gained significant attention recently, with citizen science projects playing a crucial role in data collection and community engagement. A review of existing literature reveals both opportunities and challenges in these initiatives. Urban areas, despite contributing to biodiversity decline, have the potential to support conservation efforts (Nilon et al., 2017; Monti, 2020). For example, citizen science projects in coastal regions, such as SeaPaCS, have successfully engaged diverse groups of participants to study marine plastic pollution and its impact on local biodiversity (Certoma, 2024). However, these projects often face challenges such as data quality assurance, participant retention, and the need for proper training (Li et al., 2019; Kasten et al., 2021). Studies emphasize the importance of developing standardized protocols and validation methods to ensure the scientific rigor of citizen-collected data. For instance, with appropriate training, citizen scientists can generate high-value biodiversity data comparable to that collected by experts, though specific habitats, such as bivalve zones, may present greater challenges requiring targeted training (Kasten et al., 2021). Efforts to align urban biodiversity monitoring with global conservation priorities have also gained traction. The EU Biodiversity Strategy for 2030, for example, emphasizes enhancing urban biodiversity by creating and restoring green and blue infrastructure and improving connectivity between urban and peri-urban areas (Monti, 2020). Similarly, innovative frameworks like the Biodiversity Analysis in Los Angeles (BAILA) offer valuable approaches for urban biogeography assessment, which can be adapted for coastal urban areas to better understand species distribution patterns and inform conservation planning (Li et al., 2019).

Urban marine environments represent a unique intersection between human activity and natural ecosystems, often resulting in complex interactions that significantly impact biodiversity (Montoya et al., 2006; Liu et al., 2007; Bishop et al., 2022). In cities like Barcelona (Spain), these interactions are pronounced due to high population density, extensive tourism, and various forms of pollution. Understanding the health and biodiversity of these environments is crucial for conservation and sustainable urban policy development (Blanco-Libreros et al., 2021; Pontes et al., 2021).

Over five years, environmental science students from Institut Rambla Prim (Barcelona) conducted a project monitoring the biodiversity of three prominent city beaches in Barcelona. This initiative, spanning 2018 to 2023 (excluding 2021 due to COVID-19), involved systematic sampling of biological indicators at Espigó de Sant Sebastià, Espigó de Sant Miquel, and Espigó and Banys del Fòrum (Figure 1). A significant finding was the post-pandemic increase in the Shannon biodiversity index, reflecting recovery and resilience in the urban marine ecosystem (Montoya et al., 2006; Liu et al., 2007; Bishop et al., 2022).

Figure 1 Sampling zone; Barcelona, Spain: Espigó de Sant Sebastià, Espigó de Sant Miquel, and Espigó and Banys del Fòrum. (Goole Earth)

This project not only provides data on the current state of marine biodiversity but also emphasizes its educational value. Students engaged in the monitoring process gained hands-on experience, fostering a deeper understanding of marine ecology and the importance of biodiversity preservation in urban contexts (Momota and Hosokawa, 2021). By examining the trends observed over the study period and their implications for urban marine conservation, this research contributes also to a growing body of knowledge on urban marine ecosystems and highlights strategies to mitigate urbanization's negative impacts (Claudet and Pelletier, 2004; Montoya et al., 2006; Bishop et al., 2022).

2 Results and Analysis

The biodiversity monitoring conducted over five years at three urban beaches in Barcelona—Espigó de Sant Sebastià, Espigó de Sant Miquel, and Espigó and Banys del Fòrum—revealed significant trends and changes in marine species presence and diversity (Figure 2). The study, spanning the years 2018, 2019, 2020, 2022, and 2023, with a gap in 2021 due to the COVID-19 pandemic, provides a comprehensive overview of the urban marine ecosystem's health and resilience.

The data collected show considerable variation in species composition and abundance across the sampled years and locations (Table 1). A total of 38 different fish species were identified during the study period (Gamma biodiversity). The total number of individual fish organisms recorded at each site varied significantly, with Espigó de Sant Sebastià generally showing higher counts compared to the other sites. Notably, the species *Oblada melanura* and *Sarpa salpa* were particularly abundant, contributing substantially to the overall counts. Espigó de Sant Sebastià exhibited consistently higher total counts in 2018 and 2019, driven largely by the abundance of *Diplodus sargus* and *Diplodus vulgaris*. Espigó de Sant Sebastià showed substantial variation, with the highest total count in 2018, largely due to high numbers of *D. vulgaris*, *D. Sargus*, *S. salpa* and *O. melanura*. Espigó and Banys del Fòrum had lower overall counts but displayed a unique set of species, including *Gobious fallax* and *Symphodus tinca*, contributing to the site's distinct biodiversity profile (Table 1).

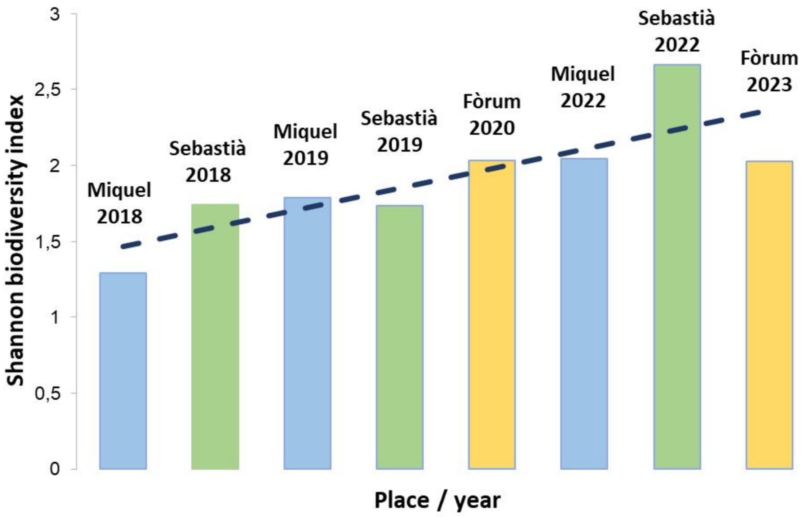

Figure 2 Evolution trend in urban marine biodiversity in Barcelona beaches

One of the key findings of the study is the significant increase in the Shannon biodiversity index (Alpha biodiversity) over the sampled years, particularly following the pandemic year 2021 (Figure 2). The Shannon index, which measures species diversity by considering both abundance and evenness, showed a noticeable rise in 2022 and 2023. In 2018, the Shannon index at Espigó de Sant Miquel was 1.29, increasing to 2.04 by 2022. Espigó de Sant Sebastià index rose from 1.74 in 2019 to 2.66 in 2022. Espigó and Banys del Fòrum had an index of ≈2.03 in 2020 and 2022, reflecting a rich and diverse marine community (Table 1 and Figure 2). These increases suggest a positive trend in biodiversity, indicating potential recovery and resilience of the urban marine ecosystem during and after a period of reduced human activity due to the pandemic (Claudet and Pelletier, 2004; Montoya et al., 2006; Liu et al., 2007; Bishop et al., 2022).

In relation to key species observations, several species showed interesting patterns. For example; *Atherina boyeri* was predominantly observed in Espigó de Sant Sebastià in 2018, with 750 individuals recorded. *Chromis chromis* had high counts in multiple years, with the highest being 457 individuals also at Espigó de Sant Sebastià in 2019. *D. sargus*, *D. vulgaris and S. Salpa* were particularly abundant (≥1000) in Espigó de Sant Sebastià (2018), contributing significantly to the total biodiversity. Finally, *O. melanura* recorded big schools (≥200) in many places and years (Table 1).

3 Discusson

This five-year biodiversity monitoring project conducted across three urban beaches in Barcelona provides key insights into the dynamics of urban marine ecosystems under anthropogenic pressures. The results indicate significant shifts in species diversity and abundance, offering important ecological implications for the conservation and management of urban coastal environments. One of the most striking findings is the increase in the Shannon biodiversity index, particularly in 2022 at San Sebastià (2.66; Figure 2, Table 1), which indicates an upward trend in species richness and evenness. This rise is especially notable after the 2021 interruption caused by the COVID-19 pandemic. Reduced human activity during the pandemic, including diminished recreation and pollution, likely facilitated the temporary recovery of marine ecosystems. Such rebounds, observed globally, underscore the resilience of biodiversity under reduced anthropogenic pressure. (Grima et al., 2020). Such findings highlight the potential resilience of urban marine ecosystems when given a break from human pressures (Ward et al., 2022).

Regarding species composition, a total of 38 species were identified during the monitoring period, with significant variations observed between the three beaches. Espigó de Sant Sebastià and Espigó de Sant Miquel sites consistently recorded higher abundances of species such as *D. sargus*, *D. vulgaris*, *O. melanura* and *S. Sarpa* (≥1000 individuals). These species are characteristic of rocky coastal habitats, suggesting that these areas offer suitable environments for such species. In contrast, Espigó and Banys del Fòrum exhibited lower overall species richness and abundance, with a different community composition dominated by species like *Gobius fallax* and *Symphodus tinca*. These differences underscore the role of habitat heterogeneity and localized environmental conditions in shaping community structure (Claudet and Pelletier, 2004; Montoya et al., 2006; Ward et al., 2022).

Throughout the study, the trophic structure remained stable, with a mean level of 3.14, reflecting a dominance of mid-trophic species (Pauly and Watson, 2005). However, the 2023 decline at Espigó and Banys del Fòrum (2.73) suggests localized shifts favoring herbivorous or omnivorous species, likely driven by changes in habitat or resource availability. One possible factor influencing these changes is the nutrient inflow from the Besòs River, a heavily polluted river that discharges near Espigó and Banys del Fòrum. The river's nutrient-rich waters, often laden with organic matter and pollutants, may promote primary production, favoring herbivorous species and altering the local food web structure. Over the long term, such eutrophication effects could lead to shifts in community composition, potentially favoring opportunistic species adapted to nutrient-enriched environments. This could reduce overall ecosystem stability and resilience if nutrient inflow persists unchecked. Additionally, the Western Mediterranean’s enclosed hot waters create a unique environment characterized by elevated temperatures and reduced circulation compared to open marine systems (i.e. Banys del forum). Such conditions may exacerbate the effects of nutrient inflow, accelerating algal blooms and further favoring herbivorous and omnivorous species. These combined factors underscore the importance of understanding localized environmental conditions and anthropogenic influences when interpreting trophic dynamics (Liu et al., 2007; Zenetos et al., 2010). Long-term monitoring programs are essential to assess the interplay between nutrient inputs, water temperature, and their ecological implications, guiding effective management strategies for urban marine ecosystems (Claudet and Pelletier, 2004; Montoya et al., 2006; Ward et al., 2022).

Temperature fluctuations during the study period may have influenced species composition and distribution. The average preferred temperature of recorded species remained around 18.92 °C, with a notable decrease at Sant Miquel in 2023 (16.31 °C) (Table 1). Such variations in water temperature, whether due to natural seasonal changes or broader climate variability, can impact the distribution of species, particularly those with narrow temperature preferences. Given the sensitivity of coastal environments to climate change, these findings underscore the importance of considering environmental variables in future biodiversity assessments (Zenetos et al., 2010; Bishop et al., 2022).

The findings of this study have also important conservation implications, highlighting the interplay of anthropogenic and natural factors in biodiversity recovery. The post-COVID-19 increase in the Shannon biodiversity index reflects multiple ecological drivers. Reduced human activity during lockdowns likely minimized disturbances such as pollution and habitat interference, creating conditions favorable for ecological recovery. Improved water quality from decreased industrial and recreational discharges and seasonal population cycles linked to breeding or migration may have also influenced species diversity (Liu et al., 2007; Blanco-Libreros et al., 2021). Additionally, artificial reefs and coastal management measures likely enhanced habitat complexity, offering refuges for marine organisms (Claudet and Pelletier, 2004; Montoya et al., 2006).

These findings underscore the potential benefits of reducing human pressures, even temporarily, and suggest that targeted management strategies, such as reducing tourism or implementing seasonal closures, could foster further ecological recovery (Claudet and Pelletier, 2004; Montoya et al., 2006; Todd et al., 2019; Blanco-Libreros et al., 2021). The distinct species profiles observed across the three beaches emphasize the need for tailored conservation approaches. For instance, protecting the rocky habitats of Espigó de Sant Sebastià and Sant Miquel could help maintain the high abundance of species like *Diplodus sps* and *O. melanura*, while specific conservation measures may be needed at Espigó and Banys del Fòrum beaches to support the unique species assemblages present there (Zenetos et al., 2010; Pontes et al., 2021). Long-term monitoring is essential to capture these biodiversity trends and inform urban marine conservation strategies. By integrating natural recovery mechanisms with active management, such as habitat restoration or artificial reef deployment, conservation efforts can better address the challenges faced by urban marine environments (Claudet and Pelletier, 2004; Momota and Hosokawa, 2021; Bishop et al., 2022).

Table 1 List of species observed and most important parameters evaluated

Species name	2018		2019		2020	2022		2023	Total (n)	Trophic Level	Preferred (Tº)
	Miquel	Sebastià	Miquel	Sebastià	Fòrum	Miquel	Sebastià	Fòrum			
Atherina boyeri	0	750	0	0	0	0	29	0	779	3,2	18,3
Belone belone	3	10	0	27	0	1	4	0	45	4,2	11,3
Botus phodas	0	1	1	1	0	0	2	0	5	3,4	15,1
Chelon labrosus	0	0	0	0	0	33	22	28	83	2,6	11
Chromis chromis	32	50	212	457	6	8	36	0	801	3,8	20,1
Coris julis	2	10	7	0	15	0	13	0	47	3,4	19
Dicentrarchus labrax	1	3	10	16	0	0	0	5	35	3,5	10,7
Diplodus annularis	1	5	0	0	0	0	8	1	15	3,6	18,3
Diplodus cervinus	0	3	0	0	0	0	0	0	3	3	19,1
Diplodus puntazzo	0	1	6	4	0	0	0	0	11	3,2	19,1
Diplodus sargus	0	1000	60	80	38	14	32	17	1241	3,4	18,8
Diplodus vulgaris	0	1000	15	28	0	0	27	3	1073	3,5	18,8
Echiichthys vipera	0	0	0	0	0	9	2	0	11	4,4	10,5
Gobius fallax	0	0	0	0	32	0	0	22	54	3,3	19,3
Gobius cobitis	1	4	0	0	0	0	0	4	9	3	18
Gobius geniporus	1	1	0	0	0	0	0	5	7	3,3	19,1
Gobius niger	1	1	0	0	0	0	0	10	12	3,3	10,8
Labrus merula	1	5	0	0	2	0	2	0	10	3,6	19,2
Lithognathus mormyrus	4	2	5	3	0	9	16	0	39	3,4	24,4
Mugil cephalus	3	10	40	47	12	0	0	0	112	2,5	27,9
Mullus barbatus	2	2	4	20	0	0	0	2	30	3,1	14,2
Mullus surmuletus	6	3	20	15	0	0	14	0	58	3,5	10,2
Oblada melanura	200	500	300	500	0	0	35	0	1535	3,4	19,6
Parablennius gattorugine	0	0	15	12	20	14	0	17	78	3,6	17,4
Parablennius pilicornis	0	0	0	0	0	0	17	0	17	3,2	26,4
Sarpa salpa	50	1000	50	280	24	22	32	93	1551	2	18,8
Scoepaena porcus	0	0	0	0	0	0	2	0	2	3,9	13,9
Seriola dumerili	0	10	0	0	0	0	0	0	10	4,5	27,1
Serranus cabrilla	2	6	10	17	0	0	5	0	40	3,4	14,4
Serranus scriba	0	0	0	0	0	0	3	0	3	3,8	18,4
Sparus aurata	0	0	1	3	1	5	7	2	19	3,7	17,8
Spicara maena	1	1	0	0	0	0	0	0	2	4,2	14,5
Symphodus tinca	0	0	0	0	27	0	0	1	28	3,3	18,9
Thalassoma pavo	2	5	0	0	0	7	0	0	14	3,5	18,7
Trachinus araneus	0	0	0	0	0	0	0	1	1	4	18,6
Trachinus draco	0	0	0	0	0	0	0	1	1	4,2	10,9
Tripterygion delaisi	0	1	0	0	0	0	0	14	15	3,4	18,7
Total	313	4384	756	1510	177	122	308	226	7796	-	-
N.º Sp's	18	26	16	16	10	11	20	17	37	-	-
Shannon Biodiv. (H')	1,29	1,74	1,79	1,74	2,03	2,04	2,66	2,03	2,66	-	-
M. Triphic Level (MTL)	3,22	3,08	3,38	3,25	3,16	3,08	3,26	2,73	3,14	-	-
Mean Preferred Tª	19,24	18,82	19,55	19,32	19,42	16,31	18,45	17,14	18,92	-	-

On the other hand, this study underscores the significant educational benefits of involving students in long-term biodiversity monitoring projects. By engaging in hands-on research, students contribute actively to marine conservation efforts while gaining a profound understanding of the ecological dynamics and challenges inherent to marine ecosystems (Kasten et al., 2021; Certoma, 2024). Such initiatives foster environmental stewardship among participants, highlighting the broader societal advantages of integrating community-based research into education (Todd et al., 2019; Blanco-Libreros et al., 2021; Kasten et al., 2021; Certoma, 2024). A key component of this project was its pre-survey training sessions, which included the use of questionnaires to evaluate and shape students' perceptions of marine ecosystems. Initially, many participants harbored a pessimistic view, asuming that Barcelona's urban beaches, located within a densely populated area, would lack substantial marine life due to high pollution levels. However, this misconception was profoundly challenged during fieldwork. Through snorkeling sessions and direct observation of the unexpectedly diverse marine life, students experienced a transformative shift in understanding. Post-survey feedback demonstrated a newfound appreciation for the richness and complexity of urban marine biodiversity. This unexpected diversity may, in part, be facilitated by the high inputs of organic matter from urban runoff and nearby river discharge, which can enhance primary production and provide resources for a range of marine species, despite the challenges of pollution.

Beyond altering perceptions, the project equipped students with practical skills, including species identification and data collection techniques. These competencies not only enhanced their scientific knowledge but also motivated some participants to extend their engagement beyond the classroom. Several students facilitated public educational events on marine biodiversity, raising awareness among local communities. Others pursued careers in eco-tourism and snorkeling guide roles within Barcelona, reflecting the broader vocational impact of the program. Such educational initiatives emphasize the interconnectedness between academic learning and community engagement, underscoring the importance of cultivating future leaders in marine conservation. By immersing students in real-world ecological challenges, this project not only bolstered their environmental awareness but contributed to a growing societal recognition of the ecological value of urban marine ecosystems (Todd et al., 2019; Blanco-Libreros et al., 2021; Momota and Hosokawa, 2021; Bishop et al., 2022). The study also highlighted other factors contributing to urban marine biodiversity, such as the absence of professional fishing, limited recreational fishing, and nutrient and organic matter inputs from the city. These insights helped both students and the local population recognize the ecological value of urban marine ecosystems and promoting stronger community engagement in marine conservation efforts.

Finally, the study may demonstrate the resilience of urban marine ecosystems under reduced anthropogenic pressure and highlights the value of continuous biodiversity monitoring in densely populated coastal areas. The observed increases in the Shannon biodiversity index and the distinct species profiles across the three sites emphasize the importance of habitat heterogeneity and targeted conservation strategies. The role of artificial barriers, nutrient inflows, and localized environmental conditions underscores the need for holistic urban planning to enhance marine ecosystem health. Moreover, the project's integration of student involvement illustrates the potential for community-based research to advance both scientific understanding and societal engagement in conservation. Future efforts should focus on expanding monitoring programs to include additional biodiversity indicators, addressing the long-term impacts of nutrient inputs, and leveraging educational initiatives to foster greater public involvement. Through collaborative approaches, urban biodiversity conservation can serve as a cornerstone for sustainable coastal development globally.

4 Future Directions

Building on the success of this project, future monitoring efforts should adopt a multi-faceted approach to enhance the scope, depth, and impact of biodiversity assessments in urban marine environments. First, expanding the geographic scope to include more urban and peri-urban beaches is essential for understanding broader patterns of marine biodiversity in response to varying levels of anthropogenic pressures. Comparing ecosystems across different urban settings will provide insights into how factors such as tourism intensity, pollution levels, and habitat heterogeneity influence biodiversity trends. Additionally, increasing the frequency and duration of sampling would enable the capture of long-term trends and seasonal variations, allowing for a more comprehensive understanding of temporal dynamics in species composition and abundance.

Second, future studies should investigate the specific impacts of different human activities, including coastal development, tourism, and pollution, on marine biodiversity. This could involve integrating additional environmental parameters, such as water quality, sediment composition, and microplastic prevalence, to assess how these factors interact with biological communities. Incorporating advanced technologies, such as underwater drones and AI-assisted species identification, could significantly enhance the precision and efficiency of data collection while also serving as valuable tools for data validation and ensuring the accuracy of results (Li et al., 2019; Condal et al, 2020).

Third, maintaining continuity in sampling is critical to addressing gaps in data series, such as the absence of data from 2021 due to pandemic-related restrictions. This gap represents a key limitation of the current study, as it interrupts the continuity of the data series and potentially obscures nuances in biodiversity trends. The missing data from 2021 may have provided valuable insights into transitional dynamics following reduced anthropogenic pressures during the pandemic lockdowns of 2020 (Grima et al., 2020). Continuous sampling is particularly important during such transitional periods to understand immediate recovery processes and inform management strategies.

However, expanding and sustaining such efforts present several challenges. Adequate funding is crucial to cover the costs of equipment, logistics, and personnel, especially for long-term projects. Additionally, consistent and rigorous training programs are required to ensure accurate data collection while minimizing observer variability. This is particularly important for initiatives involving students and citizen scientists, whose contributions can be invaluable if properly guided (Kasten et al., 2021; Certoma, 2024; Condal, 2024). Outreach and educational initiatives will also play a key role in engaging a steady stream of participants, maintaining their interest and commitment over time, and fostering broader community involvement in conservation efforts.

Finally, greater integration of citizen science initiatives can significantly broaden the scope and impact of biodiversity monitoring. Engaging students and community members not only increases the capacity for data collection but also raises public awareness of the ecological value of urban marine ecosystems. The success of similar initiatives, such as SeaPaCS, demonstrates the potential of citizen science to generate high-quality data while fostering environmental stewardship (Certoma, 2024). Addressing these logistical and methodological challenges is critical to creating robust, long-term monitoring programs capable of generating reliable data to inform urban marine conservation strategies. The insights gained from this study underscore the critical role of sustained scientific research and community engagement in fostering healthier and more resilient urban marine ecosystems. By prioritizing collaborative efforts and leveraging innovative methodologies, future monitoring initiatives can contribute to the preservation and restoration of these vital habitats for generations to come.

5 Materials and Methods

This study was conducted on three urban beaches in Barcelona, Spain: Espigó de Sant Sebastià, Espigó de Sant Miquel, and Espigó and Banys del Fòrum (Figure 1). These beaches were selected due to their representative urban coastal environments, distinct ecological characteristics, and the presence of artificial barriers, such as breakwaters and groynes. These structures enhance habitat complexity, providing refuge for diverse marine species and making them valuable for studying urban marine ecosystems (Montoya et al., 2006). Sampling surveys were carried out during the summers of 2018, 2019, 2020, 2022, and 2023. The COVID-19 pandemic prevented sampling in 2021.

Approximately 20 environmental science students participated in the sampling each year. Students received comprehensive training in marine biodiversity monitoring techniques, focusing on species identification (Froese and Pauly, 2011; Nalmpanti et al., 2023), data recording, and snorkelling safety protocols. The primary data collection method involved snorkelling surveys conducted along predetermined transects at each beach. These transects were strategically selected to encompass diverse habitats, including sandy bottoms and rocky outcrops, to provide a comprehensive assessment of local biodiversity.

During the snorkelling surveys, students visually identified fish species along the transects. Species identification was guided by use of photographic field guides, taxonomic keys, and regional sampling guides. Species that could not be confidently identified in the field were photographed for subsequent identification (Froese and Pauly, 2011; Nalmpanti et al., 2023). For each identified species, the number of individuals observed was recorded on waterproof data sheets, along with habitat information.

The collected data were used to calculate species abundance and biodiversity indices, including the Shannon biodiversity index (αH'). The Shannon index was calculated using the formula: $H' = -\sum(pi \cdot ln(pi)$ where pi represents the proportion of individuals of species i relative to the total number of individuals observed. Data from all surveys were entered into a central database for further analysis. The dataset was used to assess fish species diversity, abundance, and ecosystem health at each beach (Nalmpanti et al., 2023). Temporal trends in species composition were also examined to identify significant ecological patterns and shifts (Figure 2) (Condal et al., 2012; 2020; Condal, 2024).

To ensure methodological rigor and data reliability, students underwent extensive training prior to fieldwork. This training included theoretical sessions where teachers used photographic guides to familiarize students with local marine species and their distinguishing features. Practical training involved the use of regional sampling guides and photography techniques for accurate species identification. During field surveys, teachers actively supported students by verifying challenging observations and validating data in situ. Additionally, Condal F., a marine biologist and biodiversity expert known for developing marine image identification protocols (Condal et al., 2012; 2020; Condal, 2024), conducted independent sampling of the same sites and transects. His benchmark dataset served as a reference for validating student-collected data. Observations deemed nonsensical or outliers were excluded, and validated data were averaged to generate a corrected dataset. This dataset was used to calculate the parameters presented (Table 1). These rigorous methodologies ensured the reliability and scientific integrity of the data series, meeting the standards required for scientific publication. By combining student involvement with expert oversight, this study achieved a balance between educational impact and research quality, providing robust insights into urban marine biodiversity.

Acknowledgments

I would like to extend my gratitude to all who have been involved in sampling surveys and lab analysis. Specially teachers from Rambla Prim Institute; Carles Molina, Jorge Gómez and Vicent Martínez, and all students from Environmental Studies Certificate.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Bishop M.J., Vozzo M.L., Mayer-Pinto M., and Dafforn K.A., 2022, Complexity–biodiversity relationships on marine urban structures: reintroducing habitat heterogeneity through eco-engineering, Philosophical Transactions of the Royal Society B, 377(1857): 20210393.
https://doi.org/10.1098/rstb.2021.0393

Blanco-Libreros J.F., Riascos J.M., Branoff B., and Heery E.C., 2021, Eco-evolutionary dynamics of marine biodiversity in human-dominated coastal scapes, Frontiers in Marine Science, 8: 812202.
https://doi.org/10.3389/fmars.2021.812202

Certoma C., 2024, Il progetto “SeaPaCS participatory citizen science against marine pollution” riceve il diversity and collaboration award dell’European union’s citizen science prize 2024, Apre Magazine, 2024: 23-25.
https://iris.uniroma1.it/bitstream/11573/1715883/3/Certoma_Progetto_2024.pdf

Claudet J., and Pelletier D., 2004, Marine protected areas and artificial reefs: a review of the interactions between management and scientific studies, Aquat. Living Resour., 17(2):129-138.
https://doi.org/10.1051/alr:2004017

Condal F., Aguzzi J., Sarda F., Nogueras M., Cadena J., Costa C., Del Río J., and Mànuel A., 2012, Seasonal rhythm in a Mediterranean coastal fish community as monitored by a cabled observatory, Marine Biology, 159: 2809-2817.
https://doi.org/10.1007/s00227-012-2041-3

Condal F., Aguzzi J., Sarda F., Nogueras M., Cadena J., et al., 2020, Cabled video-observatory monitoring of seasonal rhythms in a Mediterranean coastal fish community, hal-03013945.
https://hal.science/hal-03013945/

Condal F., 2024, Marine ecosystem restoring by high-complexity artificial reefs (HCAR), International Journal of Marine Science, 14(1): 29-39. https://doi: 10.5376/ijms.2024.14.0005

Froese R., and Pauly D., 2011: fishbase, world wide web electronic publication, Version, 2(2011): 14. https://www.fishbase.se/search.php

Grima N., Corcoran W., Hill-James C., Langton B., Sommer H., Fisher B., 2020, The importance of urban natural areas and urban ecosystem services during the COVID-19 pandemic, PLoS ONE, 15(12): e0243344. https://doi.org/10.1371/journal.pone.0243344

Kasten P., Jenkins S.R., and Christofoletti R.A., 2021, Participatory monitoring—a citizen science approach for coastal environments, Frontiers in Marine Science, 8: 681969. https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2021.681969/full

Li E., Parker S.S., Pauly G.B., Randall J.M., Brown B.V., and Cohen B.S., 2019, An urban biodiversity assessment framework that combines an urban habitat classification scheme and citizen science data, Frontiers in Ecology and Evolution, 7: 277. https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2019.00277/full

Liu J., Dietz T., Carpenter S.R., Alberti M., Folke C., Moran E., and Taylor W.W., 2007, Complexity of coupled human and natural systems, Science, 317(5844): 1513-1516. https://www.science.org/doi/abs/10.1126/science.1144004

Monti S., 2020, Nature-inclusive cities: concepts and considerations, Nature Driven Urbanism, 2020: 225-247. https://link.springer.com/chapter/10.1007/978-3-030-26717-9_11

Montoya J.M., Pimm S.L., and Solé R.V., 2006, Ecological networks and their fragility, Nature, 442: 259-263. https://doi.org/10.1038/nature04927

Momota K., and Hosokawa S., 2021, Potential impacts of marine urbanization on benthic macrofaunal diversity, Scientific Reports, 11(1): 4028. https://doi.org/10.1038/s41598-021-83597-z

Nalmpanti M., Chrysafi A., Meeuwig J.J., and Tsikliras A.C., 2023, Monitoring marine fishes using underwater video techniques in the Mediterranean Sea, Reviews in Fish Biology and Fisheries, 33(4): 1291-1310. https://doi.org/10.1007/s11160-023-09799-y

Nilon C.H., Aronson M.F., Cilliers S.S., Dobbs C., Frazee L.J., Goddard M.A., and Yocom K.P., 2017, Planning for the future of urban biodiversity: a global review of city-scale initiatives, BioScience, 67(4): 332-342. https://academic.oup.com/bioscience/article-abstract/67/4/332/3065740?login=false

Pauly D., and Watson R., 2005, Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity, Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1454): 415-423. https://doi.org/10.1098/rstb.2004.1597

Pontes M., Salvador X., Parera À., Álvarez G., and Ballesteros M., 2021, Monografies de la institució catalana d'Història natural, Núm, 3: 2021 https://ichn.iec.cat/wp-content/uploads/2021/09/Monografies_de_la_ICHN_3.pdf

Todd P.A., Heery E.C., Loke L.H., Thurstan R.H., Kotze D.J., and Swan C., 2019, Towards an urban marine ecology: characterizing the drivers, patterns and processes of marine ecosystems in coastal cities, Oikos, 128(9): 1215-1242. https://doi.org/10.1111/oik.05946

Ward D., Melbourne-Thomas J., Pecl G.T., 2022, Safeguarding marine life: conservation of biodiversity and ecosystems, Reviews in Fish Biology and Fisheries, 32(1): 65-100. https://doi.org/10.1007/s11160-022-09700-3

Zenetos A., Gofas S., Verlaque M., Cinar M.E., García Raso J.E., Bianchi C.N., and Streftaris N., 2010, Alien species in the Mediterranean Sea by 2010, a contribution to the application of European union's marine strategy framework directive (MSFD), Part I Spatial distribution, Medit. Mar. Sci., 11(2): 381-493.https://doi.org/10.12681/mms.87