Study and characterization of the health status of the deep-water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846), on the Catalan coast

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ABSTRACT

The deep-water rose shrimp, *Parapenaeus longirostris*, represents a commercially and ecologically important crustacean in the Mediterranean Sea, yet knowledge about its health status and susceptibility to diseases remains limited. This study aims to assess, for first time, parasites and histopathological lesions in *P. longirostris* populations from two contrasting sites along the Catalan coast: Barcelona (highly urbanized with poor environmental quality) and La Rapita (rural zone with better environmental quality) between February 2024 and December 2024. A total of 240 individuals were sampled using bottom trawls and 150 were analyzed through classical histological techniques. The main parasites detected included ciliates in the gills (9.33%), gregarines in the intestine (8.67%), and microsporidians in muscle (3.33%) and heart (1.33%). Lesions observed were hemocytic infiltration (10.0%), encapsulation (6.67%), nodules (0.67%), and melanisation (0.67%). Notably, a higher prevalence of some parasites and pathological alterations was recorded in Barcelona (i.e., ciliates, gregarines, microsporidians, hemocytic infiltration, nodules, melanisation) compared to La Rápita. Seasonal variation influenced microsporidian infections, which peaked in spring, and ciliate and gregarine prevalence, which were the highest in summer. Most individuals exhibited condition indexes equal or higher than 1 indicating a good health status. Statistical analysis using Generalized Linear Models revealed that seasonality was the sole factor significantly affecting the shrimp condition index, whereas site, sex, and presence of parasites or lesions were not significant predictors. These findings suggest that deep-water rose shrimp is in a good overall health and most of parasites and lesions detected show low prevalences. However, it is possible an association between bad environmental quality and more diseases in *P. longirostris*, emphasizing the need for continued monitoring to inform resource management and ensure the sustainability of shrimp fisheries.

Keywords: *Parapenaeus longirostris*, histopathology, parasites, Mediterranean Sea, environmental pollution, seasonality, fisheries management.

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1. INTRODUCTION

The deep-water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846), stands as one of the most economically significant crustacean species exploited by the fishing industry, particularly within the Mediterranean region and across Europe. Ecologically, *P. longirostris* is a nektobenthic species that predominantly inhabits sandy or muddy seabeds. It is typically found at depths between 20 and 750 meters, with highest abundances between 150 and 350 meters in the Mediterranean Sea (Sobrino & García-Jiménez, 2007). There is a well-defined vertical stratification by size with juveniles found at shallower depths (100–200 m), and adults usually exceeding 200 meters depth (Ardizzone et al., 1990). Furthermore, the sex ratio also varies with depth, with females dominating at shallower levels (<200 m), the ratio is balanced between 200–400 m (Lembo et al., 1999), and males are more prevalent beyond 400 m (Abelló et al., 2002).

Since 1980, landings of *P. longirostris* have been systematically reported, with global catches steadily increasing reaching up to 26,697 tons in 2020 (FAO, 2022b). This is most likely because over the recent decades, *P. longirostris* has increased its presence and abundance on the continental shelf and upper slope of the Iberian Mediterranean (Ben Arfa et al., 2022) favored by an increase in water temperature and salinity (Mingote et al., 2024). This species, seemingly bolstered by the ongoing tropicalization of the Mediterranean Sea (Benchoucha et al., 2008); (Ungaro & Gramolini, 2006), has gained increasing importance becoming one of the principal crustacean resources for the Catalan bottom trawling fleet (NW Mediterranean Sea). According to official landing data provided by the regional government (*Direcció General de Pesca, Generalitat de Catalunya*), the Catalan bottom-trawling fishery, which operates along 580 km of the northern Mediterranean Spanish coastline generated a total revenue of 55 million euros and landed 7,854 tonnes in 2019, within the context of a multispecies fishery. However, despite its growing importance, it remains understudied when compared to other commercial crustacean species like the red shrimp *Aristeus antennatus* (Mingote et al., 2024).

Beyond its economic and social relevance, *P. longirostris* populations are vulnerable to a variety of parasites and/or pathogens. Penaeid shrimps are known to be susceptible to be infected by multiple taxa, including bacteria, fungi, and viruses. These agents may lead to tissue inflammation, melanisation, necrosis, and in some cases, tumor formation (Johnson, 1995). Moreover, they often act as hosts for parasitic organisms such as flatworms, nematodes, ciliates, and microsporidians (Zuidema et al., 2023). A notable parasitic disease is “cottony disease,” characterized by progressive whitening of the muscle, caused by the microsporidian *Ameson nesoni* (Sprague, 1950). This parasite leads to muscle degeneration, negatively affecting the sensory and nutritional qualities of the shrimp and rendering them unfit for commercialisation (Panebianco et al., 2015). Moreover, this disease is not unique to a single species; it has been reported in other shrimp species (Ramasamy et al., 2000), including the deep-water rose white shrimp in Italy (Panebianco et al., 2015) indicating its broader relevance within the fishery industry. To date, no other parasites or pathological conditions have been documented in this species. Identifying this type of biological threats can have significant consequences, not only on the health and sustainability of shrimp populations but also on the quality and safety of the harvested product destined for human consumption.

Environmental stressors, especially pollution, may influence host-parasite interactions. (Goutte & Molbert, 2022a) demonstrated that chronic exposure to contaminants can induce physiological and biochemical changes in host organisms, potentially altering the prevalence and intensity of parasitic infections. An increase in ciliate loads, particularly in gill tissues, as well as greater occurrence of microsporidians and other protozoans, has been documented in polluted environments (Khan & Thulin, 1991). Moreover, These pathologies are also exhibiting an increase in virulence (Burge et al., 2014), metabolism and fitness, ultimately leading to higher rates of transmission (Karvonen et al., 2010) due to climate change, concurrently with the populations of *P. longirostris.*

To address the potential non-described health concerns in *P. longirostris*, researchers from the Institut de Ciències del Mar (ICM-CSIC) and the Institut Català de Recerca per ala Governança del Mar (ICATMAR) started a project to study parasites and pathologies to evaluate the health status on *P. longirostris* populations along the Catalan coast. According to the Catalan Water Agency (*ACA*), the waters near Barcelona exhibit poor ecological conditions and high pollution levels, particularly in the port area with the highest presence of plastics (Balcells et al., 2023). Conversely, northern and southern ports present better water quality, with better biological and physicochemical parameters.

In this context, the present study aims to provide a detailed characterization of the parasites and associated pathologies impacting the populations of *P. longirostris*. By elucidating the spectrum of parasitic infections and their pathological consequences, this research seeks to contribute to essential knowledge for the understanding of the health status of the species with potential effects on food quality in the Catalan coast.

2. OBJECTIVES

The aim of this study is to study the health status of *P. longirostris* populations in two contrasting locations from the Catalan coast (Barcelona and La Rapita), identifying potential threats from diseases and parasites. The specific objectives are:

a. Identify and describe parasites and/or lesions through the histological study of different *P. longirostris* tissues.

b. Evaluate if parasites or histological lesions are associated to locations with different environmental conditions or to seasons.

c. Evaluate if parasites or histological lesions are associated to the condition index of the species.

3. MATERIALS AND METHODS

3.1 Sample collection and preparation

A total of 240 specimens of *P. longirostris* (Fig. 1) were collected from two distinct locations in four seasonal samplings along the Catalan coast: Barcelona and La Rápita (Fig. 2), during the period between Februay and December 2024.

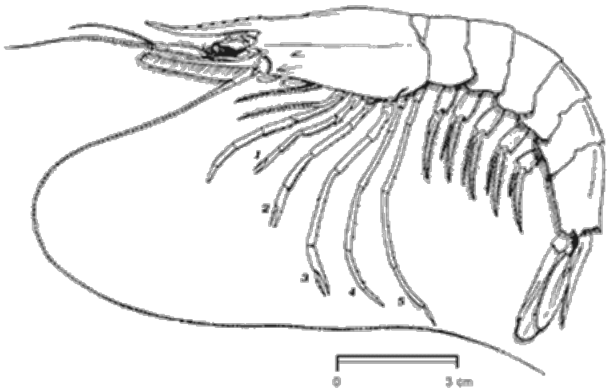

Figure 1. *Parapenaeus longirostris* (Fischer et al., 1987).

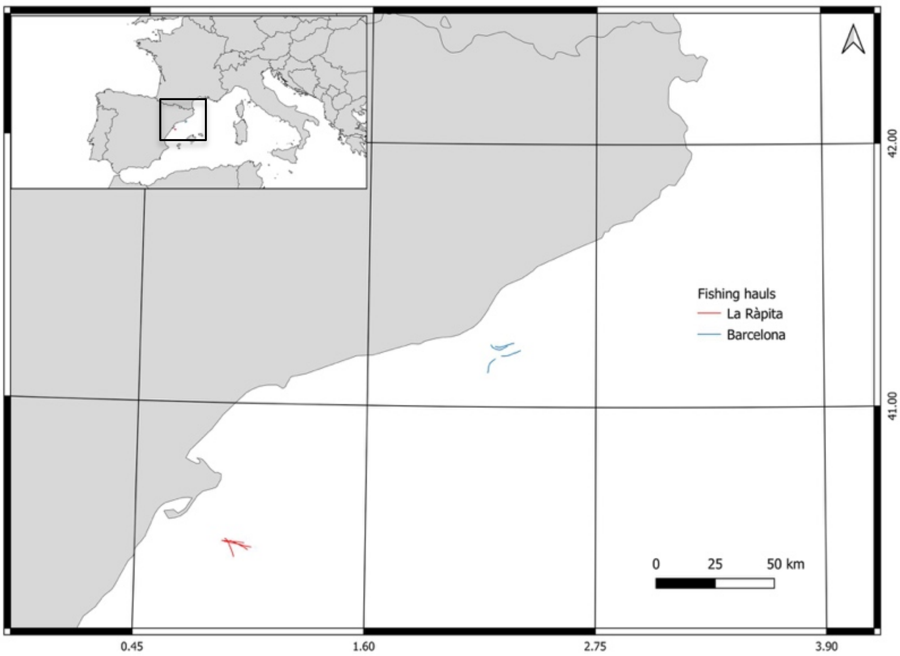

Figure 2. Map of *P. longirostris* fishing hauls used for this study, in Barcelona (blue) and La Ràpita (red).

The trawl net had a mesh size of 40 mm (square). During each trawl where this species was captured, a subsample of thirty specimens was placed in an ice-cooled container for transport to the ICM-CSIC in Barcelona. The specimens were measured (carapace length CL in mm) and weighted (body weight BW in gr).

The condition index (CI) was calculated following (Le Cren, 1951) based on the formula: CI = BW/a×CLb, where a and b represent the intercept and slope, respectively, obtained from the allometric equation logBW = log a + b logCL (Le Cren, 1951), (Froese, 2006). High CI values (≥ 1) indicate that organisms are thriving and well-suited to their environments, while low values (< 1) suggest they may be under adverse conditions in their habitats (Le Cren, 1951), (Ujjania et al., 2012).

Dissections were performed under a stereomicroscope to isolate key tissues, including gills, stomach, intestine, hepatopancreas, muscle, and gonads. Gonads were observed to determine the sex. Tissue samples were fixed in Davidson solution (Suvarna et al., 2018) for 24 hours and stored in ethanol 70% at room temperature.

3.2 Histological processing and microscopical analysis

Classical histological techniques were employed for tissue analysis (Howard, 2004) from a subsample of about 15 specimens per site and per season (N = 150). After fixation, samples were dehydrated through a graded ethanol series, cleared in xylene, and embedded in paraffin wax. Paraffin blocks were sectioned at 5 µm thickness using a microtome. Sections were mounted on glass slides and stained using hematoxylin - eosin to allow general tissue structure and potential pathological alterations to be assessed.

Histological slides were examined under a light microscope Zeiss Axioscop 2+ at various magnifications (from 5x to 100x). Digital images were captured using an integrated camera system Zeiss Axiocam 208, focusing on identifying microorganisms and histological lesions.

3.3 Data analysis

Parasites and histological lesions found were described using specialized bibliography (López-Téllez et al., 2009); (Bower & McGladdery, 1996); (Panebianco et al., 2015); (Götz, 1986); (Wang & Yao, 2007); (Frischer et al., 2017); (Gutiérrez-Salazar et al., 2015). Prevalence (%), measured as number of affected hosts for a parasite or lesion divided by total number of analysed host, were compared among sites and seasons using descriptive graphs.

The condition index (CI) was compared between specimens with parasites or histological lesions and non-affected specimens and related with sex, site and season using Generalized Linear Models (GLM) with Gaussian distribution (Crawley, 2012). Another GLM was used to evaluate the effect of total number of parasites and/or histological lesion on the CI.

4. RESULTS

From a total of 150 shrimp processed, 38 (25.3%) presented some parasite or lesion in at least one tissue. The parasites found in the different tissues were ciliates in gills (9.33%), gregarines in intestine (8.67%), and microsporidians in muscle (3.33%) and heart (1.33%). Besides, 4 lesion types were recorded, i.e., hemocytic infiltration in muscle, heart and gills (10.0%), cellular encapsulations in stomach, digestive gland, muscle and heart (6.67%), nodules in muscle (0.67%), and melanisation in gills (0.67%).

4.1 Parasites and/or lesions descriptions

4.1.1 Ciliates

These protozoarians, which are characterized by a big macronucleus, various micronuclei and epithelial ciliae, have been found in the gills of numerous individuals (Fig. 3). They are usually found solitary, attached to the gill lamellae, and without evidence of tissue lesion or histopathology.

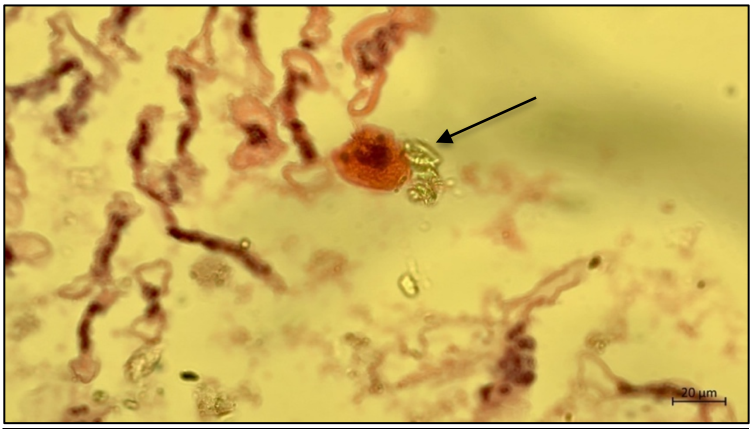

Figure 3. Ciliate (arrow) on the gill of *P. longirostris*: a single-celled microorganism covered with cilia in the apical area, macronucleus and 2 micronucli observed.

4.1.2 Gregarines

Gregarine trophozoites (Apicomplexa) were found in the lumen and are often attached to the lining of the intestine (Fig. 4). There was no evidence of tissue degeneration or lesions in the gut of any gregarine-infected shrimp. The midgut epithelium appeared normal, and the microvillous border was intact.

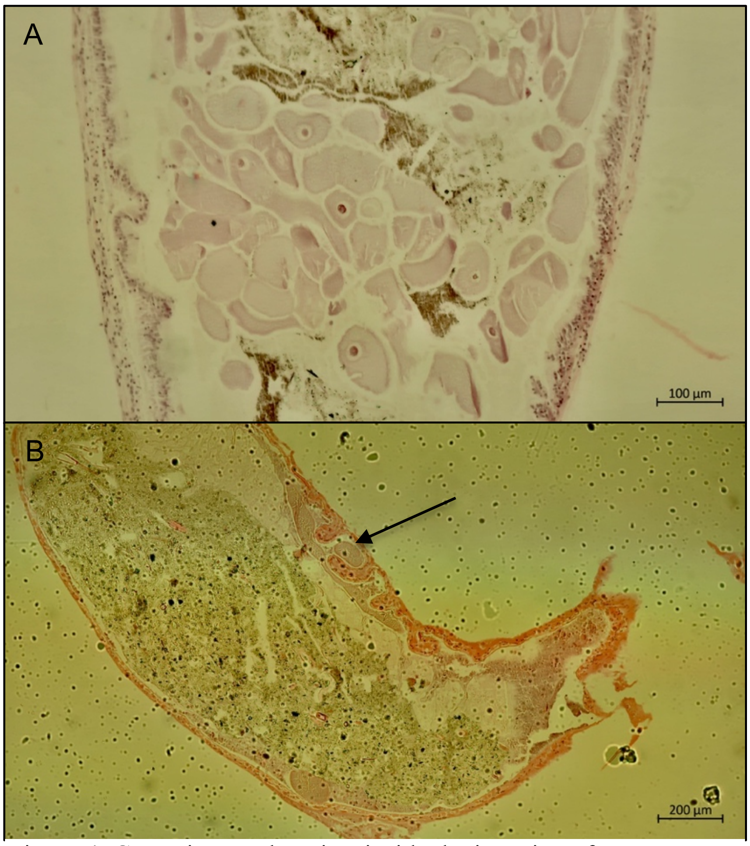

Figure 4. Gregarine trophozoites inside the intestine of *Parapanaeus longirostris*. A- Shrimp intestine fully with gregarines. B- Some gregarine trophozoites (black arrow) attached to the lining of intestine.

4.1.3 Microsporidians

The infected tissues with microsporidians (Fungi) were heart and muscle. Heart muscular tissue of healthy specimens is characterized by muscular sheets or bands, creating sub-chambers within the heart like muscular folds, that may allow for some degree of differential contraction (Fig. 5A). Histological examination at low magnification of an infected specimen has shown dyschromic muscle tissue with granular regions (Fig. 5B). At higher magnification, it is observed that part of the tissue is replaced by spore packets which are refractive (Fig. 5C)

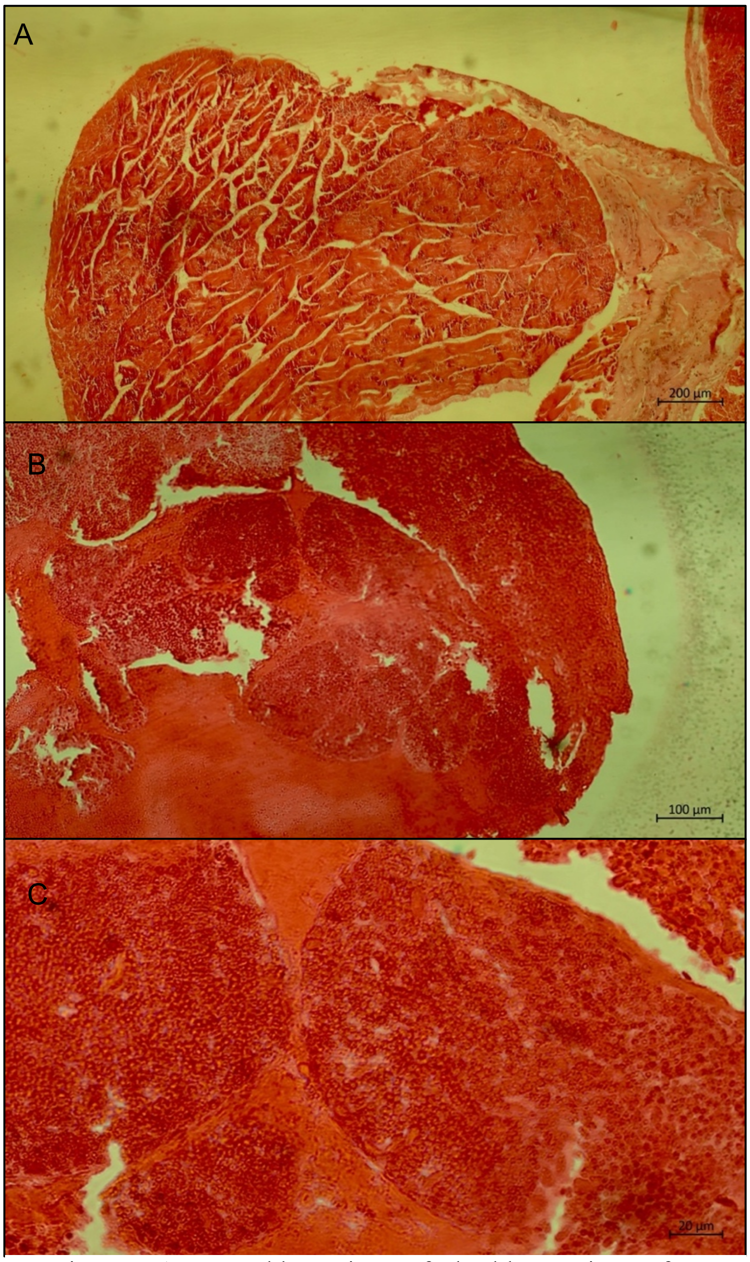

Figure 5. A- Normal heart tissue of a healthy specimen of *P. longirostris*. B-Heart of an infected specimen by microsporidians at larger scale showing granular regions. C-Detail of spore packets replacing heart tissue.

4.1.4 Hemocytic infiltration

On a variety of tissues such as heart, muscle and gills, hemocytic infiltration was present in some individuals (Fig. 6). Hemocytic infiltration is a common immune response usually related to the presence of a pathogen, but other external factors such as salinization, temperature fluctuations, or exposure to pollutants can also trigger this reaction. These stressors may compromise tissue integrity, making organisms more susceptible to opportunistic infections or causing direct tissue damage.

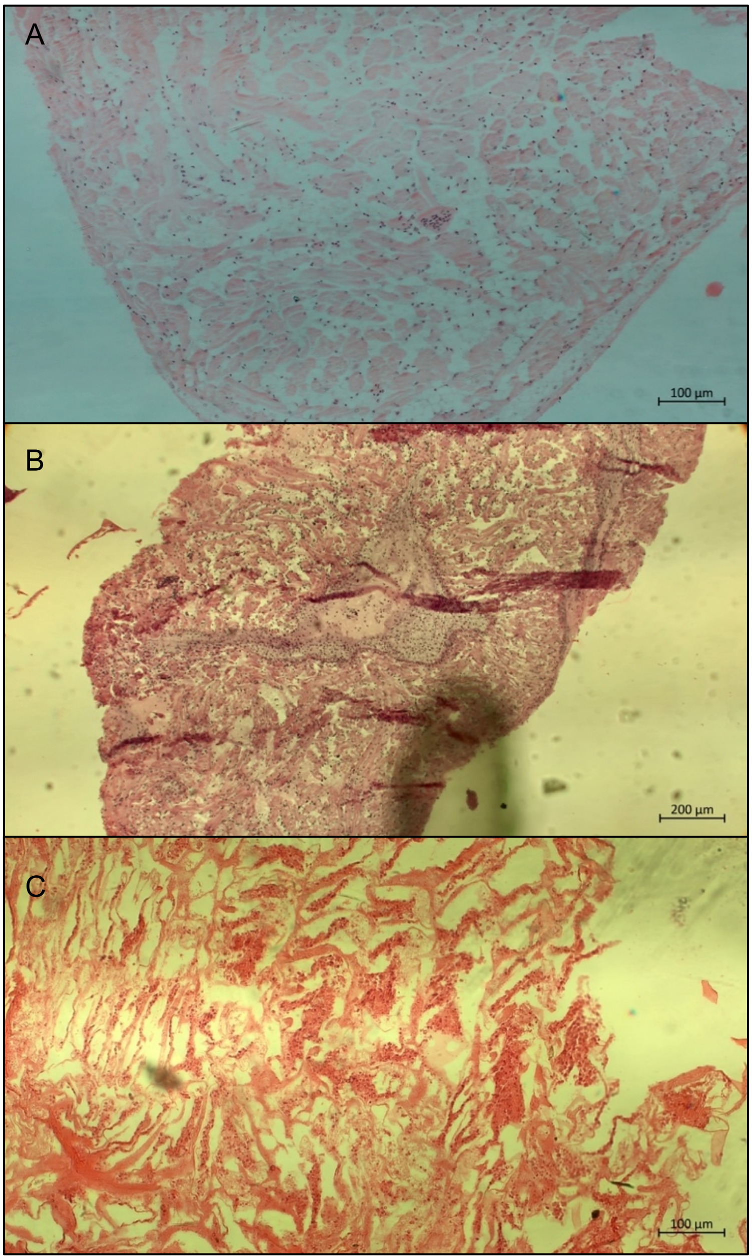

Figure 6. Hemocityc infiltrations in different tissues of *P. longirostris*: A-Muscle, B-Heart, C-Gill.

4.1.5 Encapsulations

Cellular type encapsulations were recorded on a variety of tissues such as heart, muscle, gonad, stomach and digestive gland (Fig. 7). It was not possible to identify the pathological agent in the histological section observed.

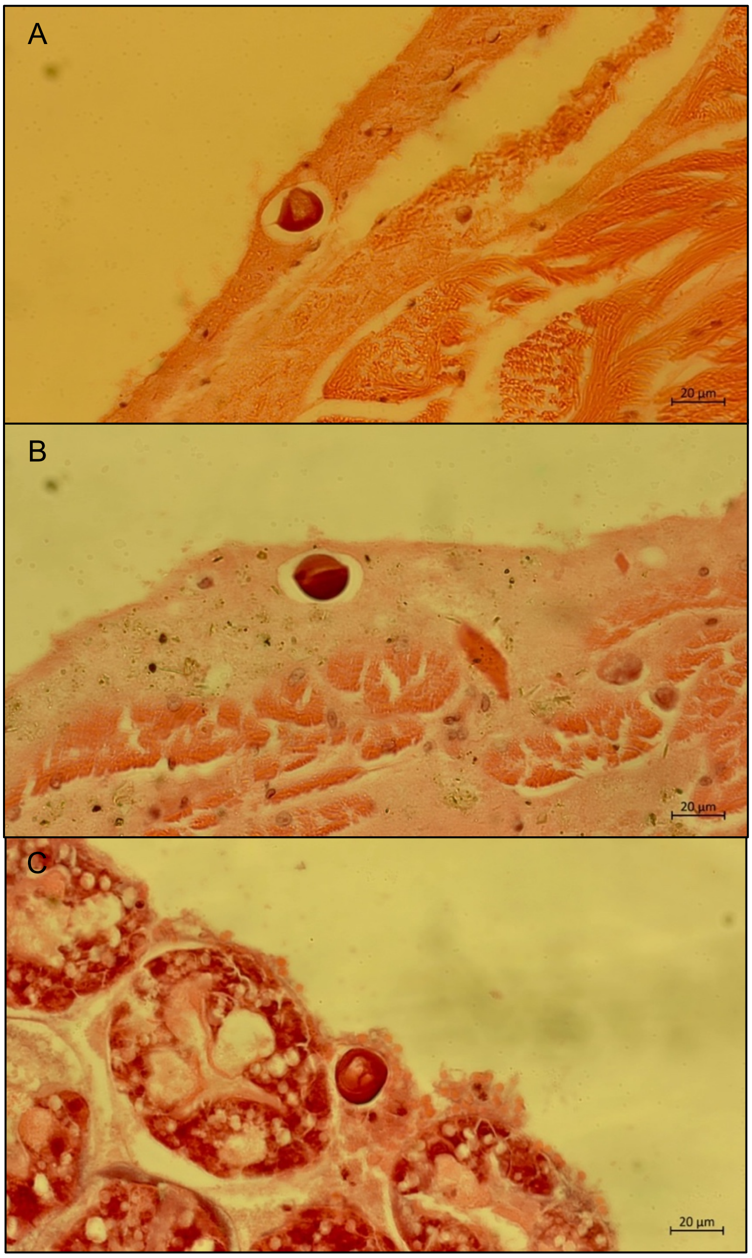

Figure 7. Encapsulations in different tissues of *P. longirostris*: A-Muscle, B-Stomach, C-Digestive gland.

4.1.6 Nodules

Only a single individual resulted affected by this lesion in the muscle. The tissue has a granular appearance (Fig. 8), often associated with a generalized inflammatory response. Formation of nodules was observed, which resulted from the accumulation of immune cells (hemocytes) around the site of the infection as part of the host's defence mechanism.

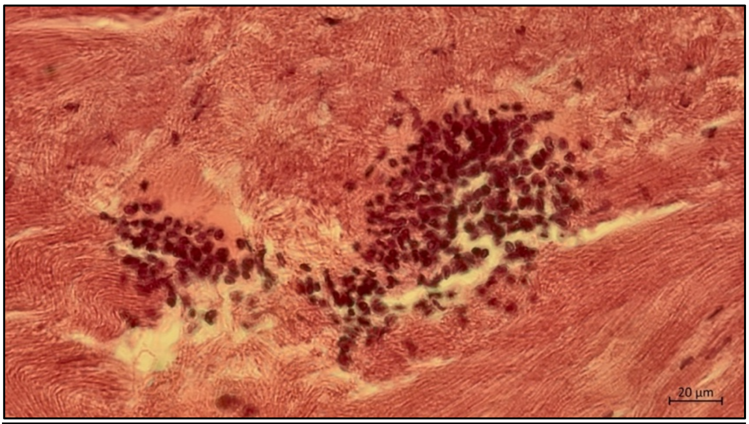

Figure 8. Nodules in the muscle tissue of *P. longirostris*.

4.1.7 Melanisation

One specimen exhibited gills with some dark-brown lamellae colour indicating melanisation (Fig. 9). In these areas, the epithelial lining of the lamellae was thickened, and the cytoplasm was swollen with a brownish infiltrate.

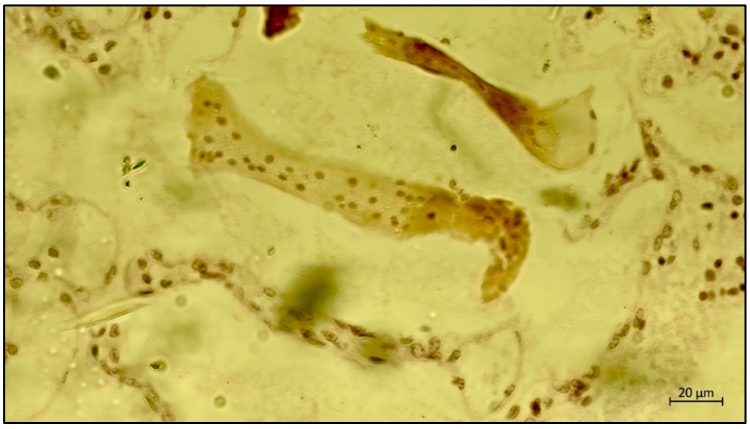

Figure 9. Gill of a *P. longirostris* specimen with darkened lamellae, characteristic of melanization.

4.2 Quantitative analysis of the histopathological study

In general, Barcelona exhibited more parasites and histopathological lesions than La Ràpita (a total of 7 vs. 5, respectively) (Fig. 10). A higher prevalence of hemocytic infiltrations and ciliates was observed in Barcelona, compared to La Ràpita. Barcelona was also the only site where nodules and gill melanization were detected. Microsporidians and gregarinae prevalence was similar in both sites. Encapsulations were the only histopathological lesion with a higher prevalence in La Ràpita, reaching 10.67% compared to 1.35% in Barcelona.

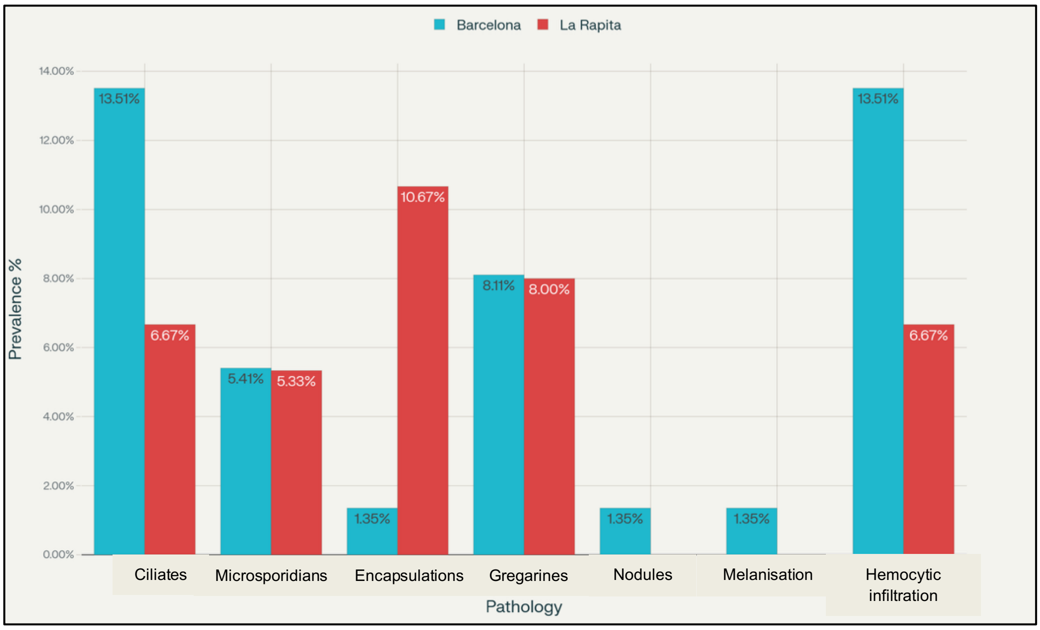

Figure 10. Bar chart showing the prevalence (%) of each parasite or histopathological lesion in Barcelona (blue) and La Ràpita (red).

Most parasites and lesions presented variability among sites and seasons (Fig. 11) without showing a clear seasonal pattern. Some of them presented very low prevalences, which were observed in some sites or seasons, such as nodules recorded only in one shrimp from Barcelona in winter or melanisation recorded in one shrimp from Barcelona in autumn. Seasonal patterns for gregarines are similar among sites with higher prevalence values in summer. Ciliates showed a prevalence peak in summer only in La Ràpita and microsporidian a peak in spring, but only in Barcelona.

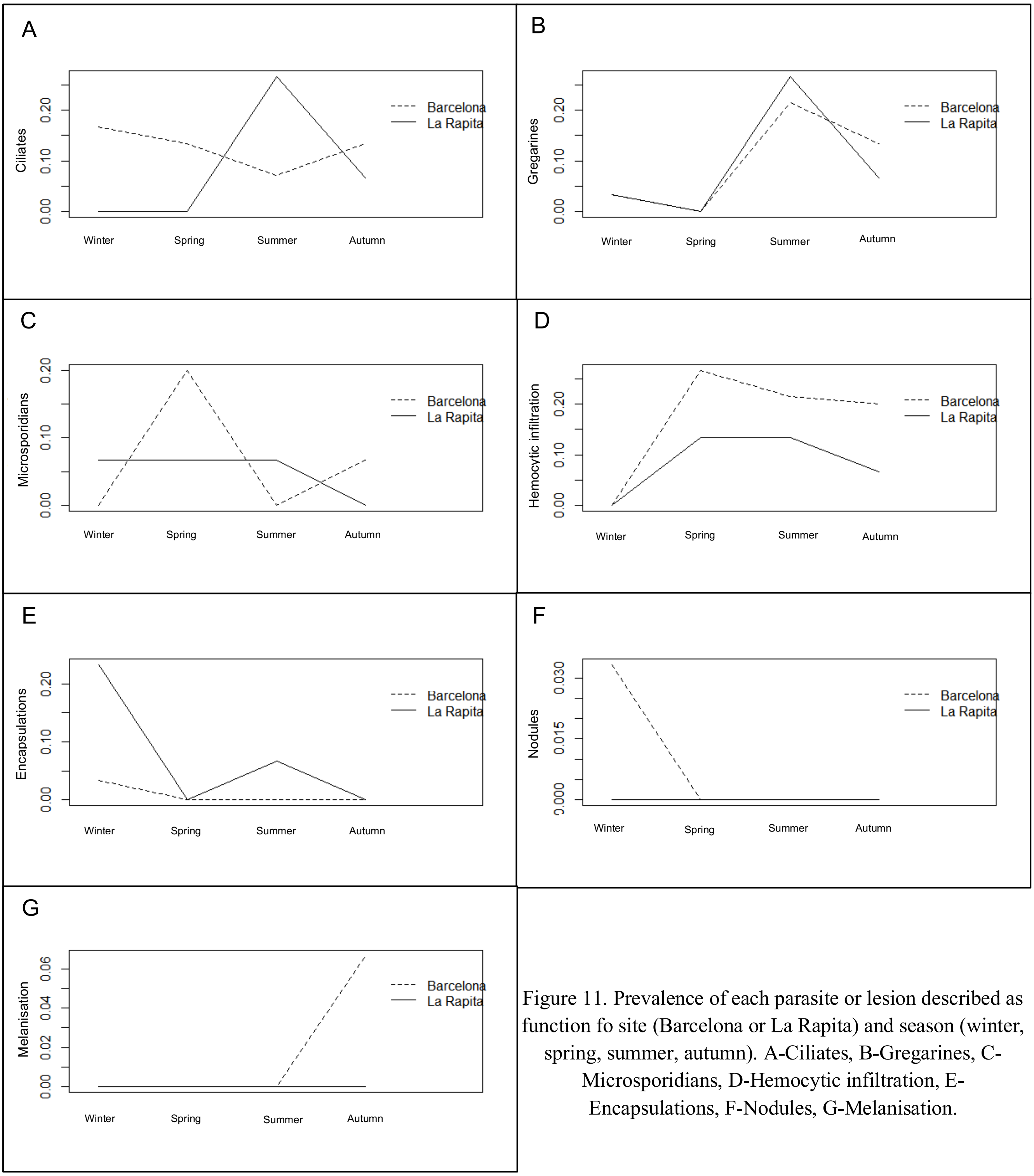

Figure 11. Prevalence of each parasite or lesion described as function fo site (Barcelona or La Rapita) and season (winter, spring, summer, autumn). A-Ciliates, B-Gregarines, C-Microsporidians, D-Hemocytic infiltration, E-Encapsulations, F-Nodules, G-Melanisation.

The condition index (CI) varies between 0.45 and 2.13, with most individuals exhibiting values close to 1, except in spring when it is slightly higher (p = <0.001) (Fig. 12). The results indicate that the unique influential factor affecting the CI is seasonality. In contrast, variables related to sex and infection (such as ciliates, gregarines, nodules, etc.) showed no significant effect on CI (Table 1).

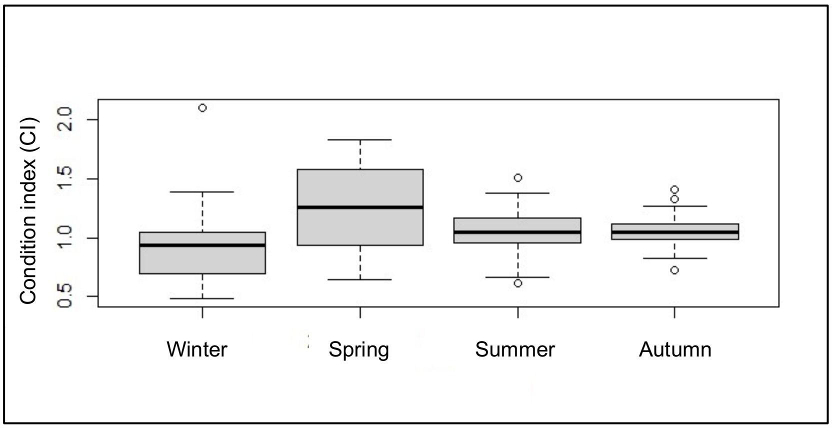

Figure 12. Box plot of Condition Index (CI) according to seasonality.

Variable	Estimate	Std. Error	t value	p value
(Intercept)	0.8696	0.0484	17.96	< 0.001
Site: La Ràpita	0.0636	0.0445	1.43	0.1551
Season: Spring	0.3485	0.0644	5.41	< 0.001
Season: Summer	0.1234	0.0642	1.92	0.0568
Season: Autumn	0.1383	0.0627	2.21	**0.0290**
Sex: Male	0.0321	0.0507	0.63	0.5280
Hemocytic infiltration	-0.0429	0.0757	-0.57	0.5718
Microsporidians	-0.0429	0.0975	-0.44	0.6606
Ciliates	0.1148	0.0745	1.54	0.1257
Melanization	0.0105	0.2642	0.04	0.9684
Gregarines	0.0859	0.0843	1.02	0.3105
Encapsulation	-0.1230	0.0970	-1.27	0.2068
Nodules	-0.0121	0.2708	-0.05	0.9645

Table 1. Results of Generalized Linear Model of condition index as function of site, season, sex, parasites and lesions. Intercept represent base values of each factor (Barcelona, winter, female and absence of each parasite or lesion). Significative p-value were highlighted in bold letter.

Total number of parasites and lesions varied between 0 to 5 (Fig, 13) . Considering the effect of this variable in the CI, no statistical differences were found (t value= 0.658, p = 0.0511).

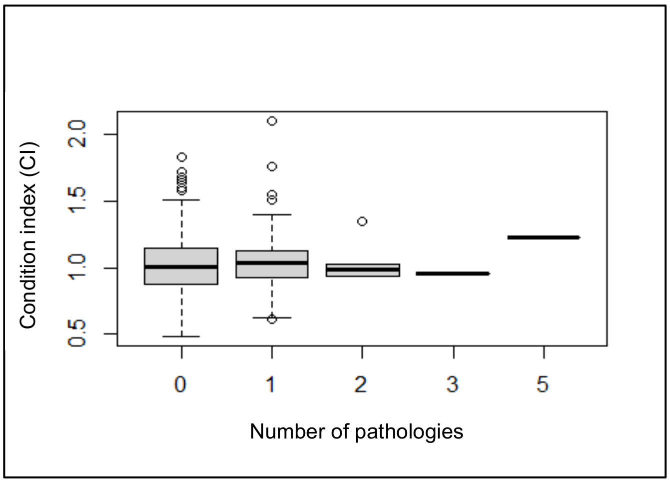

Figure 13. Box plot of Condition Index (CI) according to the total number of parasites and histological lesions.

5. DISCUSSION

This study reports for the first time a survey of parasites and lesions in the deep-water rose shrimp *Parapenaeus longirostris*. To date, the only published research concerning diseases in this species has focused exclusively on cotton disease (Panebianco et al., 2015), and no other studies have addressed the aspects investigated in this work. As reported in the result section, the parasites and lesions found were: ciliates in gills, gregarines in intestine, microsporidians in muscle and heart, nodules in muscle, hemocytic infiltration in muscle, heart and gills, cellular encapsulation in stomach, digestive gland, muscle and heart and melanisation in gills.

Ciliates are protozoan microorganisms commonly found in aquatic environments, including both marine and freshwater habitats. They are frequent epibionts and sometimes parasites on shrimp, colonizing various body surfaces and especially the gills. In shrimp, ciliate infestations are widely reported, particularly in aquaculture settings where water quality may deteriorate, promoting their proliferation (López-Téllez et al., 2009). Among the ciliate genera found on shrimp gills, both solitary and colonial forms are present. Common solitary genera include apostome ciliates such as *Gymnodinioides* and *Hyalophysa* (notably *Hyalophysa lynni,* the causative agent of shrimp black gill disease). Ciliate here studied agree with some morphological chacteristics of *Hyalophysa* spp. (globular or oval body and cilia localized in the apical zone) (Frischer et al., 2018). These ciliates were previously recorded on various shrimp species worldwide, including *Penaeus vannamei, Litopenaeus setiferus*, and freshwater genera like *Caridina* (Fernandez-Leborans et al., 2006).

When ciliate infestations are mild, shrimp may show few or no symptoms. However, heavy infestations can cause significant pathology, particularly when ciliates invade the gills. This may lead to blackening or swelling of the gills, impaired respiration, reduced feeding, difficulty molting, and increased susceptibility to secondary infections. In severe cases, mass mortality can occur, especially when ciliates act in conjunction with other pathogens or under poor environmental conditions (Frischer et al., 2018).

Gregarine infection is a worldwide disease recorded in most penaeid and other crustaceans (Bower & McGladdery, 1996). Notably, gregarines exhibit an indirect life cycle, in which polychaetes and bivalve molluscs serve as intermediate hosts. Within these hosts, the parasite develops up to the gymnospore stage, which constitutes the infective phase for shrimp. Once ingested by shrimp, gymnospores germinate, giving rise to sporozoites that invade the intestinal epithelium. Furthermore, direct transmission of the parasite via contaminated fecal material has also been described (Logan et al., 2012). In the present study, most cases of gregarine infection were mild, with only a few specimens observed per host. Nevertheless, one shrimp exhibited a severe infection, with its entire gut filled with trophozoites (Fig. 4B). Generally, the reduced absorption of food from the gut lumen or occasional intestinal blockage by gregarines is of little pathological importance for the host (Bower & McGladdery, 1996).

Microsporidians are a type of obligate, intercellular parasites of shrimps and prawns (Johny et al., 2006). In shrimp, these infections are best known locally as the cause of a condition known as "milk" or "cotton" shrimp (Panebianco et al., 2015). This parasite invades and replaces host tissues such as muscle, heart, gonads, gills, hepatopancreas, and nerve ganglia, depending on the species. As a result, this pathogen causes low-level mortalities, but the infection often leads to a whitish coloration of the shrimp, causing the muscle to become opaque and the shrimp to appear cooked, which renders the product unmarketable (Clotilde-Ba & Toguebaye, 1995). Notably, this microsporidian, *Ameson nelsoni* (Sprague, 1950) has already been reported in the deep-water rose shrimp from Italy (Panebianco et al., 2015). Future ultrastructural and molecular studies help to know if the species here recorded in the same species.

Encapsulation represents a common type of defence reaction in arthropods against invading pathogens and parasites, as well as introduced foreign bodies or injected particulate materials. This process involves the formation of a capsule-like envelope around foreign objects (Götz, 1986), characterized by a central melanized zone surrounded by layers of reactive hemocytes and degranulated, flattened (transformed) hemocytes. The encapsulation primarily results from granulocytes that have degranulated and subsequently formed closely adhered layers of flattened cells (Hose et al., 1992). Through this mechanism, the foreign element is isolated and neutralized, thus preventing it from causing harm to the host (Kulkarni et al., 2021).

In this study, only cellular encapsulation was recorded, and not hemocytic encapsulation. However, several specimens presented generalized hemocytosis. It is well established that crustacean haemocytes play important roles in the host immune response, including recognition, phagocytosis, melanisation, cytotoxicity, and cell–cell communication (Johansson et al., 2000). This infiltration is due to the accumulation of hemocyte cells in the tissues as an immune response to external agents or alterations, causing inflammation of the shrimp intestinal epithelium and necrosis (Gutiérrez-Salazar et al., 2015).

Hemocytical nodules are formed by numerous hemocytes acting synergistically to trap microorganisms or big antigens that cannot be removed by phagocytosis. These nodules undergo the subsequent activation of melanisation and destruction of microbes (Wang & Yao, 2007); (Van de Braak et al., 2002). In this study, nodules have only been found in muscle tissue, with large concentrations of hemocytes. This lesion type is commonly caused by bacteriae *Vibro* spp., responsible for mortality of cultured shrimp worldwide (Chandrakala & Priya, s. f.). The most common causes for the proliferation of this bacterial infection are adverse environmental conditions, like poor soil and water quality and excess organic matter in the water (Chandrakala & Priya, s. f.). It could explain the presence of hemocytical nodules only in Barcelona, the study area where water exhibit poor ecological conditions and highand high anthropogenic pollution levels including high concentrations of marine litter (Balcells et al., 2023) and the highest concentrations of both trace metals and organic pollutants in monitoring studies along the Catalan inner continental shelf (Pinedo et al., 2014); (Ribó et al., 2016).

Melanisation, or black gill, is symptomatic of several causes of gill disease. These causes can be infectious (such as viruses and bacteria) or non-infectious (including vitamin C deficiency and exposure to pollutants) (Chong, 2022). In this process, hemocytes catalyse the oxygenation of phenols, leading to the synthesis of the dark pigment melanin, which manifests as symptomatic darkened gills (Frischer et al., 2017).

The quantitative analysis showed seasonality in some parasites, presenting higher prevalence in spring (microsporidians) or summer (ciliates and gregarines). Some studies show that during hotter months, due to high intensity of solar energy, the moulting process is favoured (Jayasree Sr et al., 2001), thus enhancing the invasion of parasites. Previous studies demonstrated that gregarines infections varied with temperature and the prevalence was higher in summer than winter (Chakraborti & Bandyapadhyay, 2011). Comparably, (Hudson & Lester, 1992) and (Utz, 2004), found that shrimp are more easily infested by ciliates in summer, although infestation persists almost all year-round. Regarding microsporidia, seasonal trend in the prevalence was not found in crustaceans (Rk et al., 1996).

Studies have shown that the influence of environmental conditions and pollution can cause physiological and biochemical changes in hosts affected by parasites (Goutte & Molbert, 2022b). This pollution is mainly associated with marine litter, most of which consists of plastics (Balcells et al., 2023). Compared to the coastal waters of Barcelona, La Ràpita marine waters are generally classified as good according to the Catalan Water Agency (*ACA*), with very good biological quality and good physicochemical quality.

Our results showed a higher prevalence of some parasites and lesions in Barcelona compared to La Ràpita, with the exception of encapsulations, which were more prevalent in the latter. This finding is consistent with the notion that environments subject to greater anthropogenic pressure and pollution tend to support higher parasite loads and associated pathologies (Khan & Thulin, 1991). Adverse water quality conditions increase shrimp stress level, thus, making them more susceptible to diseases (Boyd & Clay, 1998); (Kautsky et al., 2000).

For example, microplastics (MPs) act not only as persistent pollutants but also as substrates that facilitate the colonization and transport of microorganisms, including viruses, bacteria, and fungi. These organisms can persist on MP surfaces for variable durations, creating opportunities for infection dissemination within marine organisms (Valencia-Castañeda et al., 2024). Moreover, significant increases in ciliates, particularly in gill tissues, along with a greater prevalence of microsporidians and other protozoans, have been specifically associated with contaminated environments (Khan & Thulin, 1991). Also, (Hudson & Lester, 1992) found that when water quality decreased, the ciliate *Zoothamnium* increased while the ciliate *Cothurnia* numbers decreased, demonstrating that some ciliate species are prone to proliferate in more polluted environments.

Finally, this study indicates a generally good health status for this shrimp species along the Catalan coast, determined by the condition index (CI) and a low overall prevalence of parasites and lesions. The CI is a critical quantitative index used to assess the physiological status of aquatic populations across time and locations. Through its variations, CI reflected the influence of both biotic and abiotic factors such as habitat changes, nutrition and physiological factors (Le Cren, 1951); (*Bagenal, T.B. and Tesch, F.W. (1978) Age and Growth. In Bagenal, T., Ed., Methods for Assessment of Fish Production in Fresh Waters, 3rd Edition, IBP Handbook No. 3, Blackwell Science Publications, Oxford. - References - Scientific Research Publishing*, s. f.); (Jones et al., 1999); (Hossain et al., 2013); (Lalrinsanga et al., 2012); (Solanki et al., 2020). We can therefore determine that the health status of *P. longirostris* is good, and that the studied pathologies do not have a significantly negative impact on the CI.

While such findings are expected in wild populations, this preliminary research provides valuable baseline information for this commercially important species in the region. It also highlights the need for future monitoring to support resource management and conservation efforts. Although this represents an initial step toward assessing the impact of human activity on this marine resource, further studies will be essential to better understand how anthropogenic factors influence the development and progression of diseases in shrimp populations.

6. CONCLUSIONS

The main purpose of this study was to assess, for the first time, the health status of the deep-water rose shrimp (*Parapenaeus longirostris*) populations along the Catalan coast through the identification of parasites and histopathological lesions, and their potential associations with environmental and biological factors. The main results showed that

ciliates, gregarines, and microsporidians were the most common parasites, and hemocytic infiltration and encapsulation were the most frequent lesions. The higher frequency of certain pathologies in more polluted areas suggests that environmental stressors could facilitate disease outbreaks. However, the overall low parasite and lesion prevalence indicated that most shrimps were in good health status.

From the results of this study, a recommendation would be to stablish a long-term monitoring of *P. longirostris* health, including parasite–pollution interactions, to ensure ecosystem sustainability and to safeguard the viability of this important fishing resource.

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ACTIVITIES UNDERTAKEN DIRECTLY BY THE STUDENT

The activities carried out directly by the student were the following:

- The histological processing of the samples, from dehydration for paraffin embedding, sectioning the samples, and staining procedures
- The thorough observation of the slides using a microscope
- The thorough observation of the preserved tissues under a stereoscope
- The data processing
- The writing of this Master's Final Project.

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