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Editorial

Environmental Stressors and Pathology of Marine Molluscs

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1. Introduction

Mollusca is one of the most species-rich phylum of the Animal Kingdom, comprising a wide range of both terrestrial and aquatic organisms. Molluscs generally show a soft body mostly enclosed within a hard shell with a protective role. However, even if they share a similar basic body plan, the group often shows great variability and diversity in form and habit [1,2]. Of the more than 70,000 recently described species, roughly 44,000 show worldwide distribution in seas [3], although bivalves and gastropods have expanded their distribution also in freshwater ecosystems. This last class is present in all terrestrial ecosystems except for permanent ice.

The main classes of molluscs include the Class Gastropoda (~40,000 species; e.g., abalone, conches, periwinkles, whelks, limpets, land snails and slugs, etc.), the Class Bivalvia (~8000 species; e.g., mussels, oysters, clams, etc.), the Class Cephalopoda (~700 species; e.g., octopus, squid, cuttlefish, etc.), and the Classes Polyplacophora and Scaphopoda (~1000 species; i.e., chitons and tusk shells, respectively).

However, while some pelagic taxa have ocean-wide distribution, others such as non-marine taxa (i.e., terrestrial and freshwater) are threatened by anthropogenic activities due to their narrow to extreme endemism [4]. Indeed, freshwater and terrestrial molluscs species are the leading group in the red list of many countries, so included on the IUCN Red List [5–7]. Therefore, in this regard, we can state that organisms in their natural environments are often subjected to continuous environmental stress conditions, whose synergistic interaction with anthropogenic stressors (e.g., chemical, etc.) can amplify their effects [8]—but what does the term stress mean?

It is difficult to give an exhaustive explanation of the word "stress". However, an early definition of stress was proposed by Selye [9,10], and then overhauled by several authors over the years [11–20]. In brief, the concept shared by all authors is that stress can be defined as a physiological response of the organism to a stressor (i.e., the variable that causes this response). Indeed, depending on the level of intensity and duration of exposure, stress is observed as a threat to homeostasis, even in organisms with higher tolerance and plasticity [21]. Thus, the perception of a stressor promotes an immediate response: positive effects (eustress) if the stress is of mild intensity, and adaptive responses with possible maladaptive or negative implications (distress) if generated by greater severities [22]. This concept has since been fully investigated in recent years. In fact, many scientists have turned their attention to hormesis, closely related to the initial disruption of homeostasis [23]. Therefore, an adaptive biological response of an organism to moderate stress is defined as hormesis [24]. This phenomenon is a useful tool to study dose-response relationships, as low-dose exposures (to multiple chemical and physical agents) promote protective/beneficial effects in contrast to higher doses [25], as well as providing important information on biological plasticity (i.e., environmental hormesis) [26].

In addition, exposure to one or more etiologic agents (e.g., physical, chemical, biological, etc.) may expose invertebrates to disease [27–29]. The effects and interactions between pollution and pathogens can have significant effects on the ecology and physiology of both farmed and wild molluscs [30].

1.1. Physical and Biological Factors

Physical factors (i.e., temperature, salinity, and hydrographic features) affect spatial distribution as well as biological aspects including feeding, reproduction, growth, respiration, osmoregulation, and parasite–disease interactions [2]. However, the synergistic effect with other environmental variables (e.g., depth, substrate type, food availability, turbidity, etc.) may have greater consequences than a single factor.

In addition, molluscs are usually preyed upon by different groups of organisms (e.g., fish, birds, mammals, crustaceans, echinoderms, flatworms, etc.) [2,31,32]. Predators probably represent the most important cause of natural mortality, also capable of influencing population growth and size structure in addition to overall abundance and local distribution patterns [2,33–35].

1.2. Climate Change

Climate change is global long-term shifts in average temperature conditions and weather patterns, directly or indirectly attributable to anthropogenic activities. Global warming will therefore have serious implications for natural and human systems [36]. In the coming years, different intensities of ocean warming, acidification, oxygen depletion, or productivity shortfalls will simultaneously affect the global ocean surface [37].

Thus, the main effect of warming will be to shift the distribution of species based on their metabolic temperature tolerances [38–42], and warming will also have important effects on biotic factors [2].

In this context, another important aspect is ocean acidification. Increased levels of atmospheric CO_2 result in increased levels of dissolved CO_2 in the oceans, thereby reducing the availability of carbonate ions essential for calcifying marine organisms such as molluscs [43]. Another serious consequence of global warming is the decrease in dissolved O_2 content in the world's oceans [44]. Thus, the synergy of the above-mentioned stressors can have serious implications on survival, growth, and metamorphosis, especially during the larval stages of molluscs [45].

1.3. Alien Species Introduction

Invasive alien species (IAS) are organisms introduced by humans, either accidentally or intentionally, outside their area of origin. Often, they are key drivers of serious long-term direct and indirect impacts on both the environment and human life. Therefore, IAS represent the second most common cause of biodiversity loss after habitat destruction [46].

Synergies with other drivers of global changes promote invasions with serious implication on native species, communities, and ecosystems [47], through mechanisms such as competition, predation, hybridization, disease transmission, parasitism, burrowing activity, and rooting [48].

For instance, Strayer [49] highlighted the negative effects that some IAS (i.e., aquatic plants, fish, crustaceans, and molluscs) have on native mollusc populations. The most striking example is that of the zebra mussel (*Dreissena polymorpha*), able to completely change the physicochemical properties and structure of the invaded environment as well as change the structure of the entire animal and plant community [49].

1.4. Environmental Contaminants

Molluscs, particularly gastropods and bivalves, are suitable organisms (bioindicators) to assess the contamination levels of terrestrial, freshwater, and marine ecosystems worldwide [50–54]. This fact is related to some important features such as their widespread distribution, abundance, sedentary habits, body size, and, often, their ecological and/or economic relevance [55]. For instance, these features enabled the development of the "Mussel Watch Program" (MWP), namely the longest running continuous and upgraded monitoring program for chemical contaminants and biological indicators of water quality, based on the collection and analysis of bivalves and sediments [56,57]. Thus, management, surveillance, and monitoring are of paramount importance as the pollutants may have adverse effects on populations of benthic assemblages ranging from changes in structure to decline and local extinction, including impacts on public health [58].

Therefore, molluscs' responses to environmental stress and contaminants have been investigated by several authors [59–68], including related pathological aspects [28,69].

1.5. Major Disease-Causing Agents

The major disease-causing agents of marine molluscs are bacteria, viruses, fungi, protozoans, trematodes, turbellarians, nematodes, and parasitic crustaceans [70]. These pathologies can have important impacts on wildlife populations, fisheries, and aquaculture industries. However, due to the preciousness and economic importance of bivalve molluscs, there is a lot of information about the diseases that affect them, both inherent to farmed and wild species (e.g., [28,71–79]), also being frequently reported as vectors responsible for diseases in humans [80–83].

Molluscs are usually bred in estuarine and coastal environments often contaminated by human activities [2,84]. Their filtering ability makes these organisms biological accumulators capable of concentrating various pathogens in their tissues [2].

Journal of Marine Science and Engineering has dedicated a Special Issue to marine molluscs, focused on environmental stressors and their effects, including pathology. Contributions should be original articles on the following topics:

- Environmental pressures: alien species introduction and environmental contaminates;
- (Eco)toxicological studies;
- The use of new bioindicators/tracers of environmental contamination;
- The condition and structure of mollusc populations;
- Factors affecting geographic distribution (physical, chemical, and biological factors);
- Climate change (e.g., climate warming, acidification, hypoxia);
- Change in feeding attitude (e.g., filtration rate, particle processing, absorption efficiency);
- Factors affecting reproduction, settlement, and recruitment;
- Factors affecting natural populations and cultured molluscs (e.g., bacterial and viral infections, biotoxins, pollutants);
- Major disease–causing agents (e.g., bacteria, viruses, fungi, or parasites);
- Defense mechanisms of marine molluscs.

The aim is to stimulate and collect new research data on marine molluscs, especially bivalves, from around the world. For more information, please contact the editors.

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