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Review Article

Mussel: a potential pollution indicator in the aquatic ecosystem and effect of climate change

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Abstract

The study of ecological indicators, defining and establishing the means of measuring the health of the environment, is of great importance. The most important elements of ecosystems are the biological components, and environmental impact assessment of ecosystems will therefore require that these components are seriously laid out. It is, for example, not sufficient to assess the water quality by the use of physicochemical parameters, although their determination can be carried out much more rapidly. There exists, in general, a relation between species composition and water quality. It is well known that mussels are extensively utilized as a biological indicator of pollution of both marine and freshwater ecosystems. The reason is that the mussel is a sessile, filter-feeding, and able to accumulate within its tissues many of the contaminants. In addition, mussels show a wide geographical distribution as they permit the survey of extensive coastal and inland areas. The contaminants accumulated in the tissues of mussels may cause a "stress syndrome" with alteration to their physiology. On the other hand, global warming does affect the pH level, especially the marine water resulting increase in acidity. This can be the outcome of the existing genetic variation in natural populations of mussels. They because allow themselves to adapt to declining pH levels in the aquatic ecosystem caused by carbon emissions. We, therefore, focus on the factors that possibly affect the mussel biodiversity in aquatic ecosystems in relation to climate change as well as pollution concerned.

Keywords: Aquatic pollution, Bioindicator, Ocean acidification

Introduction

Anthropogenic CO_2 emissions have led to increasing global mean temperatures and ocean acidification. Because both processes are occurring instantaneously, to better recognize their significances on marine species their combined effects must be experimentally evaluated.

The existence of both organic and inorganic pollutants in the marine environment is referred to as marine pollution. The occurrence in excess quantity of such compounds can adversely affect the ecological quality of the ecosystem, which can lead to alterations in characteristics of the ecosystem (Viarengo and Canesi, 1991). Among several types of similar organic compounds, polycyclic aromatic hydrocarbons (PAHs) are present in aquatic ecosystems and are capable of inducing carcinogenic or mutagenic effects to organisms (Figure 1), and hence they have received considerable attention in the literature (Balcıoğlu, 2016; Necib and Mzoughi, 2017). Inorganic compounds can include metals as a natural constituent of the marine environments, but metals and other inorganic compounds that might naturally occur can also become toxic if present at levels beyond certain thresholds (Necib and Mzoughi, 2017). An important factor that contributes to imbalance in organic and inorganic compounds which adversely affects the ecological quality of aquatic environments is anthropogenic activities (Holt and Miller, 2010). Evaluations of the ecological conditions of marine and coastal ecosystems are thus particularly important so as establish important baselines where data is lacking, and such as for the purposes or regular monitoring efforts at high impact locations, e.g., where domestic and industrial waste discharges are higher (Viarengo and Canesi, 1991; Ponce-Vélez et al., 2006).

Biological Indicator

Several species have been used as bioindicators of environmental pollution, ultimately serving to help describe the ecological quality of the ecosystem (Gazioğlu, 2018; Ogbeibu and Oribhabor, 2002; Clarke et al., 2003). Certain criteria and properties that must be fulfilled by a species for it to be considered as a bioindicator. These include that the species is:

(i) sedentary or sessile;
(ii) tolerant to wide ranges of salinity and potentially high concentrations of contaminants,
(iii) abundant in the surveyed area,
(iv) possible to collect quickly and in sufficient amounts for laboratory analyses; and
(v) a species for which a simple correlation should exist between the average concentrations of contaminants in the environment and tissues of the organism (Phillips, 1990; Alkan et al., 2020).

Several species which meet such criteria have been used as bioindicators to provide an estimation of temporally related changes in the concentrations of pollutants in ambient environments around them (Holt and Miller, 2010).
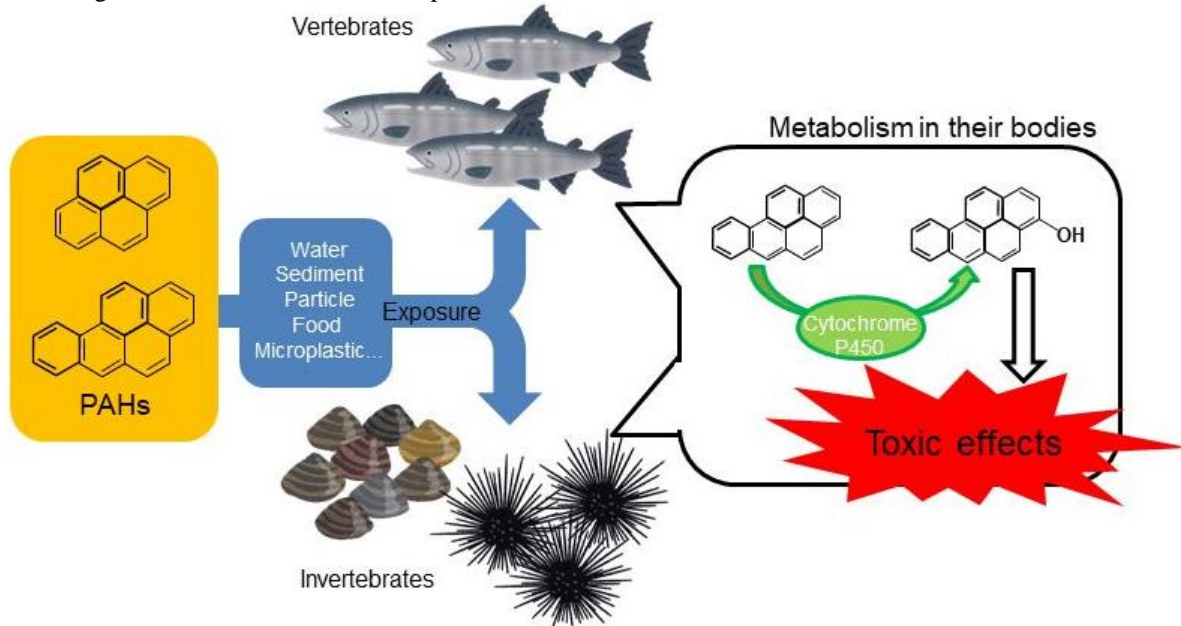

Fig. 1. Fate and toxic effects of PAHs in the aquatic ecosystem (Honda and Suzuki, 2020).

Mussel as an Indicator

Mussels belonging to class Bivalvia from the phylum Mollusca fulfil the general prerequisites for being a bioindicator (Figure 2). Hence, mussels have been used rather extensively in environmental monitoring programs in the field (Alkan et al., 2020; Ülker et al., 2020; Simav et al., 2015; Viarengo and Canesi, 1991; Phillips, 1977) suggested that mussels are the best choice as bioindicators for use in evaluation and monitoring-based assessments of biological effects of pollutants upon ecosystems. Consequently, mussels have been used as bioindicators in marine and coastal environments to assess and monitor the levels of pesticides, hydrocarbons, metals, and microplastics (D. Phillips, 1976; Viarengo and Canesi, 1991; Li et al., 2019). Furthermore, mussels have been used as bioindicators to facilitate the evaluation of the presence of zoonotics such as the *Cryptosporidium andersoni C. parvum* and *C. meleagridis* (Oliveira et al., 2016).
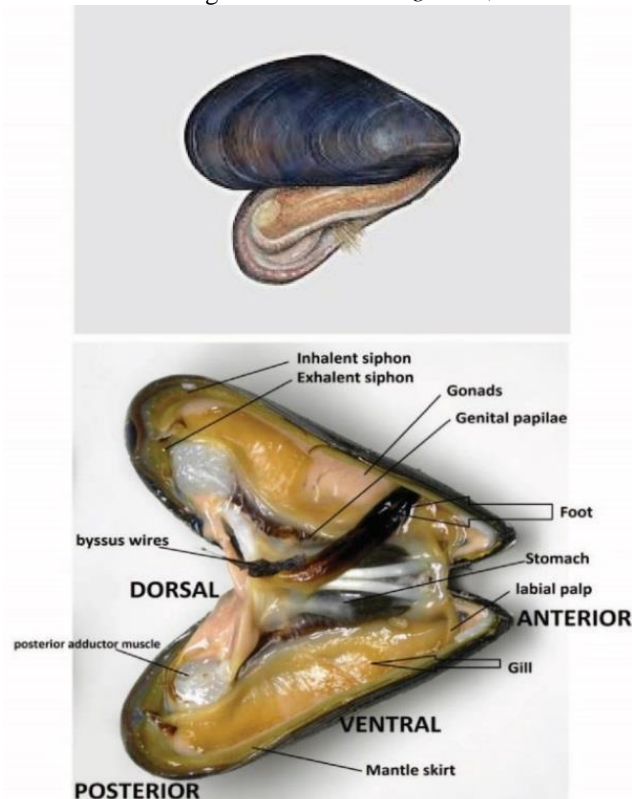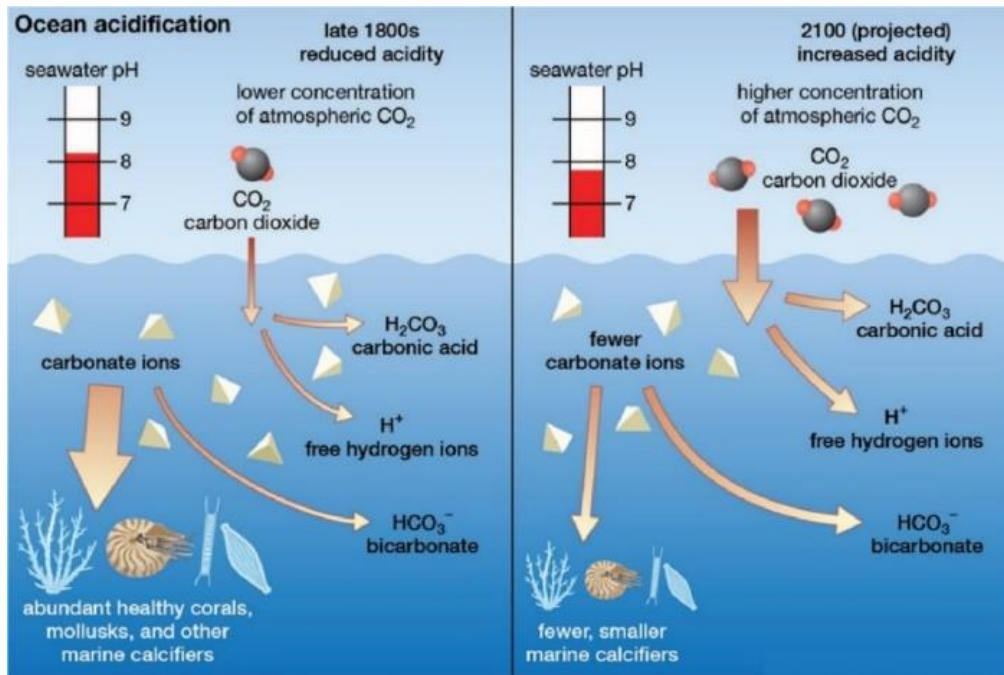

Fig. 2. General anatomy of mussel (Delahaut, 2012).

Fig. 3. Oceanic acidification and its possible impacts on marine organisms (Rafferty, 2020).

Climate Change Effect on Mussel

Up to one third of global carbon dioxide emissions are absorbed by the oceans (Borunda, 2019; Ülker et al., 2018; Townhill et al., 2017). The ocean is a natural sink for carbon dioxide (CO_2); however, the increase of anthropogenic emissions is changing the ocean chemistry by lowering the seawater pH, and causing a reduction in the availability of carbonates (CO_3^{2-}) and biogenic calcium carbonate ($CaCO_3$), a process widely known as ocean acidification (Caldeira and Wickett, 2003; Feely et al., 2009; Gattuso and Hansson, 2011; Gazioğlu and Okutan, 2016).

From 1994 to 2007, the global oceanic sink for anthropogenic carbon dioxide was 34 billion metric tons (Gruber et al., 2019). This oceanic sink of carbon dioxide results in increasing ocean acidity (Figure 3), reduce carbonate ion concentrations and saturated states of biologically essential calcium carbonate and other minerals (Broecker and Peng, 1974, ; Williamson and Turley, 2012). The impacts of ocean acidification have been documented for varied marine organisms (Williamson and Turley, 2012). For mussels, several studies have indicated that increasing ocean acidification drastically and adversely effected growth rate (Berge et al., 2006), immune responses (Bibby et al., 2008), and larval survival through recruitment (Talmage and Gobler, 2009). In one study, mussels collected in the Pacific Northwest Ocean from 2009–2011 had shells that were 32 % thinner on average compared to shell thickness levels for samples collected in the same location in the 1970s (Pfister et al., 2016). This indicated the types of significant impacts that can occur from ocean acidification with respect to mussel shells and mussel ecology, and one example of how this taxon can be not just a short term bioindicator, but a potentially long-term one as well. Additionally, laboratory studies have indicated that certain mussel species or populations

might have relatively unexpected high genetics-based resiliencies so as to be able to better withstand longer-term changes in the environment, like from ocean acidification (Bitter et al., 2019; Gazioğlu et al., 2015).

Discussion and Conclusion

There is a clear need for careful assessment and monitoring of aquatic pollution using an appropriate bioindicator. Mussels, and even sometimes just the presence of certain mussels species that may be intolerant too low to moderate levels of pollutants (e.g., see Mychek Londer et al., 2020), are considered as suitable bioindicators of environmental pollution. Further, when mussels are used as bioindicators, they can facilitate determinations of anthropogenic impacts such as from climate change (Zippay and Helmuth, 2012). Notably, particularly persistent mussel species that can adapt to harsher conditions, or others that cannot and which become locally extirpated where once previously documented, can both serve as bioindicators of environmental change. Thus, assessments are required to elaborate upon the dynamics that might influence such tolerances, including such as related to genetic, physiological, and mineralogical aspects of mussel shell dynamics. Additionally, because many environmental impacts impact relatively localized populations and ecosystems differently, the responses from mussels across different areas need to be accounted for. As the scales of such endeavours grow concomitantly with the potential looming impacts such as from climate change, needed approaches and assessments might become increasingly complex and will require the continued development of predictive models (Pfister et al., 2016). It is clear that there are many issues to be investigated in the use of mussels as an indicator for climate change. Further, unique ways to assess and monitor biodiversity, such as including the use of environmental DNA (eDNA) (Mychek Londer et al., 2020) to establish where

bioindicator species like mussels will be of paramount importance to understand their long term-responses from climate and increasing other numbers of anthropogenic impacts.

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