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Editorial

Larval Settlement on Marine Surfaces: The Role of Physico-Chemical Interactions

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Biofouling is the association of sessile aquatic organisms that rapidly settle on artificial hard substrata, thereby posing a large problem worldwide since its growth often causes severe damage to submerged structures. Biofouling on ships' hulls and surfaces of coastal structures, equipment employed in the marine industry, and hydrotechnical infrastructures constitutes a major economic and technical issue. Accordingly, international efforts are being exerted toward the development of antifouling systems because biofouling not only increases static and hydrodynamic loading but also affects corrosion characteristics and impedes underwater inspection and maintenance.

On the other hand, biofouling leads to the formation of a well-structured community on natural hard substrata characterised by an ecological succession and can be considered an important source of biodiversity, whose long-term preservation controls the trophic chain of coastal ecosystems. The primary form of fouling consists of microorganisms that mainly settle on virgin surfaces. They are represented by bacteria, microalgae, and their products that form biofilm. The secondary form of fouling is represented by organisms that need biofilms for their settlement and growth. They can be subdivided into "hard-fouling" taxa, such as corals, bivalves, serpulids, and barnacles, and "soft-fouling" taxa, such as algae, sponges, bryozoans, hydrozoans, and tunicates.

In all cases, there is a very close relationship between larval settlement and the type of substratum in question since the ecological succession of the fouling community in coastal marine ecosystems directly depends on interactions between organisms and surfaces. Due to their texture, microstructure, roughness, colour, and chemical composition, the various types of hard substrata affect organisms' settlement by favouring dominant species or preventing the settlement of biofouling organisms. The impact on the ecosystem biodiversity of the resident community caused by the extensive use of anthropogenic substrata requires attention due to the various unpredictable effects that can occur. In some conditions, artificial substrata can enhance biodiversity and productivity at a local scale in depauperated areas and positively contribute to overall regional productivity, but they can also lead to the recruitment and selection of invasive species by acting as a collector for larvae negatively affecting local biodiversity. Therefore, the influence of a substratum's physico-chemical interactions on the settlement of various organisms of the macrofouling community represents an essential factor in choosing an appropriate artificial surface for application in a variety of coastal marine ecosystems.

In this Special Issue, I present contributions that focus on various aspects of the evaluation of marine larval settlement on both natural and artificial surfaces, including pro-fouling and anti-fouling systems. The eleven papers included address the knowledge gap regarding larvae–surface interactions.

Five papers concern the morphology of adhesive specialisations and the settlement behaviour of the larvae of the principal macrofouling taxa, such as corals, barnacles, bivalves, and tunicates.

Based on a staining technique using the vital dye neutral red, Shefy and colleagues (2021) [1] propose a new method for evaluating surface selection behaviour and the success of metamorphosis for the planula larvae of the Red Sea coral *Stylophora pistillata* in the presence of conspecific larvae, which are considered fundamental for shaping coral reef communities.

Raine et al. (2020) [2] focus on reconstructing the position and morphology of the secretory glands on the antennules of the cypris larvae of two common species of barnacles (*Balanus amphitrite* and *Megabalanus coccopoma*), which are temporary adhesive structures used for initial settlement on a selected substratum.

Marčeta et al. (2022) [3] evaluate the influence of season, site, depth, and invasive species with respect to the natural settlement of Pectinidae bivalves on artificial substrata consisting of net bags in commercial mussel parks, presenting these organisms as promising new candidates for eco-sustainable shellfish farming.

Manni et al. (2022) [4] present a fine 3D-reconstruction of the tadpole-shaped larval anatomy of the solitary ascidian *Halocynthia roretzi*, a species reared for commercial purposes, with particular attention paid to the anterior adhesive papillae, which exhibit dynamic changes in their response to contact with a surface during larval settlement.

Cima (2022) [5] investigates the presence and migration of circulating haemocytes inside the embryos and larvae of the colonial ascidian *Botryllus schlosseri*, which possesses an innate immunity fundamental for its survival, adaptability, worldwide spread, and ecological success. The author also discusses hypothesized roles in (i) cell renewal, (ii) scavenger activity of apoptotic cells from tissues in resorption during metamorphosis, and (iii) defensive/protective activity concerning spatial competition and contact with biofilms during settlement.

Three papers concern the effects of the physical characteristics of the submerged surfaces.

Ambrose et al. (2021) [6] consider the recruitment, settlement success, and persistence of zygotes of the brown alga *Fucus spiralis* with respect to various types of natural bedrocks, whose distribution can determine patterns of benthic communities. Their results indicate that grain size and surface free energy directly affect the settlement of propagules, whereas surface roughness is not a predominant factor.

Richard et al. (2021) [7] evaluate the effects of ultraviolet-C light on biofouling settlement, while also considering synergistic effects with respect to the properties of the surface material. The authors observed that the reflectance of the substratum particularly influences biofouling settlement, as steel panels were more colonised than polycarbonate panels, specifically by bryozoans, serpulids, and tunicates.

Hirose and Sensui (2021) [8] present an interesting review of their studies regarding the selective effects of substrata on the settlement of ascidian larvae. The functional properties of surfaces, such as their wettability, hydrophilicity, oleophilicity, and nanostructures, are discussed, yielding potential implications for both reducing biofouling and the recruitment of invasive tunicates.

Finally, three papers consider the effects of the chemical characteristics of substrata, including those of antifouling paints and alternative, less-toxic systems.

Cima and Varello (2022) [9] analyse the effects of various trade antifouling paints commonly used on various submerged surfaces—e.g., ship's hulls, piers, buoys, and marine platforms—on the larval settlement and metamorphosis of the colonial ascidian *B. schlosseri*. Highlighting the toxic mechanisms of biocides released in the immediate surroundings or acting by contact, the authors remark upon the importance of testing antifouling components before their practical use to avoid potential long-term negative impacts on benthos communities.

Parisi et al. (2022) [10] present an extensive review on the comparative effects of commonly used antifoulant paints containing biocides and eco-friendly antifoulants on the antioxidative defence mechanism and larval settlement of the mussel *Mytilus galloprovincialis*. According to the authors, knowledge of these parameters could aid the development of antifoulants with low or zero environmental impact in order to reach one of the goals of the U.N. Agenda for Sustainable Development set for 2030.

Baldanzi et al. (2021) [11] report the potential application of a non-toxic, inexpensive surface as an eco-friendly antifouling system that is less harmful than paint. It is composed of a conducting polymer, namely, poly-3,4-ethylenedioxythiophene (PEDOT), which exhibits significant potential for deterring the settlement of barnacle cypris larvae (similar to that of trade antifouling paints).

Advancing our understanding of larvae–surface interactions will certainly be a great boon with respect to our understanding of substratum selection, settlement mechanisms, and species recruitment. I expect that these contributions will help address the challenges of future innovative eco-engineering designs, yielding the best solutions for industrial protection together with coastal ecosystem preservation.

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