UTILIUM

Introduction

Biofouling refers to the attachment of organisms to a surface in contact with water over time, and begins with the growth of a bacterial community called a biofilm. Its growth can progress to a point where it provides a foundation for seaweed, barnacles, and other organisms to grow, some of which may be invasive species.

Biofilms - the cause of biofouling

The primary cause of biofouling are complex communities of microorganisms (bacteria, fungi and viruses) that attach to any water submerged surfaces and become known what is called a biofilm[1]. When biofilms mature they create a coating over themselves that's known in the marine world as "slime" because it's slippery by nature. Once the slime is in place, biofilms are essentially indestructible. The slime also signals to the biofilm community that it's time to recruit various marine invertebrates like algae, barnacles or mussels for example.

The mechanism by which marine invertebrates is known thanks to recent research. The biofilms create structures called metamorphosis-associated contractile structures (MACs) that have two functions[2]. One is to create the perfect landing place for a variety of marine larvae, including those of sponges, cnidarians, bryozoans, mollusks, and annelids, and secondly to induce metamorphosis - resulting in the transformation of marine larvae to adults! When the hull of a ship/boat begins to look like an upside down rock pool then this is called biofouling - see the boat in Figure 1 as an example.

Figure1: biofouling on the hull of a yacht (Royal Melbourne Yacht Squadron, September 2023)

Impacts of marine biofouling

- Increased shipping costs:
  - dry-docking of vessels is required regularly to manage biofouling

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[1] Qian, Pei-Yuan, et al. "Marine biofilms: diversity, interactions and biofouling." *Nature Reviews Microbiology* 20.11 (2022): 671-684.

[2] Freckelton, Marnie L., Brian T. Nedved, and Michael G. Hadfield. "Induction of invertebrate larval settlement; different bacteria, different mechanisms?." *Scientific Reports* 7.1 (2017): 42557.

- increased drag caused by biofouling organisms leads to increased fuel costs.
- maintenance of infrastructure and the use of special materials to protect submerged surfaces is constantly constant and is estimated to cost the shipping industry at least $100 Billion pa.
- the combined costs of these three outcomes is over $150 billion USD per annum[3]

- Reduced performance: biofouling reduces the speed and manoeuvrability of ships and yachts and reduces the durability of marine structures such as buoys, and navigation and shoreline infrastructure.

- Spread of invasive species: Invasive species are non-native plants, animals, or microorganisms that, when introduced to new environments, can outcompete native species and disrupt ecosystems[4,5]. Many of these invaders find their way onto boats and other watercraft, clinging to their hulls and equipment. These stowaways can come from various sources, such as ballast water or biofouling. Once introduced, invasive species can have harmful consequences for native ecosystems. They often lack natural predators or diseases that can keep their populations in check, allowing them to proliferate rapidly and outcompete native species for resources such as food and habitat. This can result in the displacement or decline of native species, alteration of community structures, and disruption of ecological processes.

- Climate change:
  - Increased fuel consumption is a direct result of biofouling on ship hulls through increased hydrodynamic drag making it harder for vessels to move through the water[6]. To overcome biofouling resistance ships need to burn more fuel to maintain required speeds. Increased hydrocarbon fuel consumption leads to a proportional increase in greenhouse gas emissions which will contributing to global warming[7].
  - Altered ecosystems are the result of biofouling organisms transported on ship hulls establishing and spreading in new environments. These non-native species can severely disrupt local ecosystems and affect the carbon and nutrient cycles of the affected regions, potentially influencing climate change indirectly through ecosystem changes.

Current treatments for marine biofouling

There are several treatments available for marine biofouling, including:

- Anti-fouling coatings: these coatings contain biocides like copper that prevent the growth of biofilms on surfaces. However, they can have negative environmental impacts and are toxic to aquatic life[8].

- Hull cleaning: regular cleaning of ship hulls can remove biofilms and prevent the growth of larger organisms, However, this can be expensive and time-consuming because it usually entails dry docking. Recently hull cleaning robots have entered the market, but some do not

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[3] Liu, De, et al. "Research Progress on New Environmentally Friendly Antifouling Coatings in Marine Settings: A Review." *Biomimetics* 8.2 (2023): 200.

[4] Lewis, John A., and Ashley DM Coutts. "Biofouling invasions." *Biofouling* (2009): 348-365.

[5] https://www.agriculture.gov.au/biosecurity-trade/pests-diseases-weeds/marine-pests

[6] https://news.iwlearn.net/cop-26-biofouling-managements-important-contribution-for-reducing-greenhouse-gas-emissions-from-ships-featured-successfully

[7] https://www.glofouling.imo.org/post/ship-s-biofouling-management-reduces-ghg-emissions

[8] https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/toxicants/copper-2000

collect the fouling material and allow it together with any invasive species to drop into the ocean.

- Anodic biofouling control systems: these systems use an impressed current applied to copper anodes to accelerate the dissolution of copper ions, that inhibit the propagation of marine life and prevent biofouling, but as mentioned above copper is not healthy for our oceans.
- Ultrasonic treatment of a ships hull: this requires attachment of equipment to the hull and continual power even whilst docking.

Biofouling is a significant issue in many industries

Here are some of the key industries and sectors where biofouling is a concern:

- Maritime and shipping: biofouling on ship hulls is a significant issue. It increases hydrodynamic drag, which can lead to increased fuel consumption, green house gases and operational costs.
- Aquaculture: biofouling can impact aquaculture operations by accumulating on fish cages, nets and equipment. It can affect water quality and fish health by restricting water flow.
- Recreational boating: the hulls and equipment of recreational boats are all at risk. Antifouling coatings are commonly used to manage fouling on pleasure craft. Racing boats and yachts still require divers to clean their boats every few weeks to remove biofouling. In addition, boat ramps are often slippery thanks to biofouled concrete.
- Ports and harbours: structures such as piers, pilings, and buoys in ports and harbours can experience biofouling. Maintenance is necessary to ensure the safety and functionality of these structures[9].
- Oil and gas: biofouling can affect offshore oil and gas infrastructure, including underwater pipelines and drilling equipment[10].
- Renewable energy: biofouling can be a concern for renewable energy systems, such as underwater tidal and wave energy generators. Fouling on these structures can reduce energy production efficiency.
- Water treatment: biofouling can occur in water treatment plants, affecting the efficiency of pumps, filters, and other equipment. It is essential to manage biofouling to maintain the quality of treated water.
- Marine research: scientific instruments and sensors deployed in marine environments can be affected by biofouling. Researchers must take measures to prevent or control fouling on their equipment.
- Desalination: biofouling can impair the operation of desalination plants, particularly in the intake systems where seawater is drawn into the facility for desalination[11].
- Microbial-induced corrosion in the water bore pumps: iron-eating bacteria are a significant factor that has a detrimental effect on borehole pumps[12]. This leads to clogging and corrosion of the pump's parts and can eventually lead to complete system failure.

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[9] Hopkins, Grant, et al. "Managing biofouling on submerged static artificial structures in the marine environment–assessment of current and emerging approaches." *Frontiers in Marine Science* 8 (2021): 759194.

[10] Kyei, Sampson Kofi, Dennis Asante-Sackey, and Eric Danso-Boateng. "Biofouling in the petroleum industry." *Advances in Nanotechnology for Marine Antifouling*. Elsevier, 2023. 165-191.

[11] Jamieson, Tamar, and Sophie C. Leterme. "Influences and impacts of biofouling in SWRO desalination plants." *Critical Reviews in Environmental Science and Technology* 51.12 (2021): 1281-1301.

[12] Skovhus, Torben Lund, Richard B. Eckert, and Edgar Rodrigues. "Management and control of microbiologically influenced corrosion (MIC) in the oil and gas industry—Overview and a North Sea case study." *Journal of biotechnology* 256 (2017): 31-45.

- Mining industry: microbial-induced biofouling can occur in mining equipment that is exposed to water, leading to reduced efficiency and increased maintenance costs[13].

Conclusion

Marine biofouling has several adverse effects on marine ecosystems, including reduced efficiency, environmental problems, water pollution, and the transfer of invasive aquatic species. These effects can have serious consequences for the marine environment, and it is important to address them to ensure the health of the ecosystem.

Utilium's solution is to create plant-based coatings that do not harm the ocean, marine life or the places it is applied. Our plant oil-based coatings prevent biofilms attaching the water-affected to submerged surfaces and can be used in any situation.

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[13] Singh, Ajay K., and Ajay K. Singh. "Industrial cases of microbial induced corrosion." *Microbially Induced Corrosion and its Mitigation* (2020): 81-106.