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Opinion

Perspectives in Microbial Manipulation for Bioremediation of Coral Reefs

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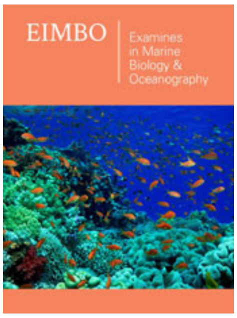

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Introduction

Coral reefs are one of the most important ecosystems in the world, with great ecological and economic importance. However, coral reefs are under threat due to various anthropogenic factors, including climate change, overfishing, and pollution by oil spills. These factors have resulted in the decline of coral reef health and biodiversity, leading to the urgent need for effective mitigation and restoration strategies. The widespread use of petroleum products results in frequent oil spills [1], which have been reported for decades [2-4]. Ocean spills are the most common, with approximately 103 tons of oil spilled into the ocean each year [5]. Unfortunately, oil transport routes in the ocean often pass near important coral reefs, and many major oil spills in history have occurred near coral reef areas [4]. Offshore oil and gas production has also increased since the 1990s due to the worldwide demand for oil and gas, which has resulted in a significant increase in the potential for accidents in marine environments and coral reefs [6].

The potential risks of oil exploitation to coral reefs are well-established. However, there remains a significant gap in the availability of efficient and sustainable remediation strategies that can effectively protect and clean up reefs impacted by oil spills. One of the main emergency response strategies for oil spills at sea is the use of chemical dispersants. However, dispersants have been shown to be more harmful to corals than the oil itself [7]. Thus far, an effective and sustainable remedial strategy for coral reefs impacted by oil spills is yet to be developed. In recent years, research has shown that microorganisms play a crucial role in maintaining coral health and resilience. The microorganisms that are associated with corals, including viruses, dinoflagellates, archaea, bacteria, and fungi, collectively form the coral microbiome [8-10]. These microorganisms contribute to various beneficial functions, such as photosynthate production, micronutrient supply, pathogen protection, nitrogen fixation, and UV-damage protection [11-18]. The coral animal and its associated microorganisms are commonly referred to as a coral holobiont, which represents a dynamic system whose members may vary depending on environmental conditions and daily requirements [19]. Moreover, microbiome interactions can drive holobiont biology and define its phenotype [20]. These microorganisms can be used biotechnologically to improve the health and resilience of corals. Just as they are already widely used to improve the health of various animals, including humans. These beneficial microorganisms are known as probiotics.

Microorganisms are also known for their excellent ability to decompose a wide variety of pollutants, including petroleum hydrocarbons. This capability can be used to remove contaminants and restore degraded ecosystems. This methodology is known as bioremediation. Recently, this immense microbial versatility has been used to develop sustainable strategies for environmental mitigation and environmental recovery. The idea of manipulating the microbiome of corals, combining probiotic coral microorganisms with petroleum hydrocarbon-degrading microorganisms is proving to be a promising strategy for bioremediating oil-contaminated coral reefs. Studies based on this methodology have shown that corals when impacted with oil, survive the impact, as they are more resilient to contamination. Furthermore, there is a significant degradation of petroleum hydrocarbons, allowing the mitigation of the environment [9,21,22].

A recent study used a bacterial consortium composed of 10 different species isolated from the coral of specie Mussismilia harttii corals. This bacterial consortium was able to degrade 72.75% of total petroleum hydrocarbons and 56.20% of 38 polycyclic aromatic hydrocarbons in 10 days, while preserving zooxanthellae photochemical ability [21]. Another study evaluated a multi-domain microbial consortium comprising bacteria, filamentous fungi, and yeast, isolated from seawater and corals of species Millepora alcicornis and Siderastrea stellata. This bacterial consortium was able to mitigate oil impacts, substantially degrading oil components and improving coral health in the presence of oil [22]. However, the effectiveness of microbial manipulation for coral reef bioremediation is still limited by several factors. One of the main challenges is the delivery of microbes to the targeted site. Microbes need to be delivered in sufficient numbers and in a way that ensures their survival and colonization in the environment. Moreover, the potential impact of introduced microbes on the coral reef ecosystem needs to be carefully evaluated to avoid unintended consequences.

Therefore, it is extremely important that successful mesocosm-scale experiments begin to be tested in the natural environment. In field experiments, researchers try to assess how ecological systems respond to natural conditions and verify whether results obtained under controlled conditions can be applied in a natural environment. These are important to validate findings obtained in controlled environments and to obtain information about the natural variability of ecological systems under different environmental conditions. Field experiments are the next step for this promising technology to be put into practice (Figure 1). In order to minimize the anthropic impacts on coral reefs. Corals are among the most sensitive animals on our planet. A biotechnological product that is proven not to harm the health of these animals is robust evidence that it will not harm other animals on the coral reef. Therefore, it is extremely important that such bacteria are isolated from the coral reefs themselves and are very well studied in terms of their metabolic diversity and pathogenic potential.

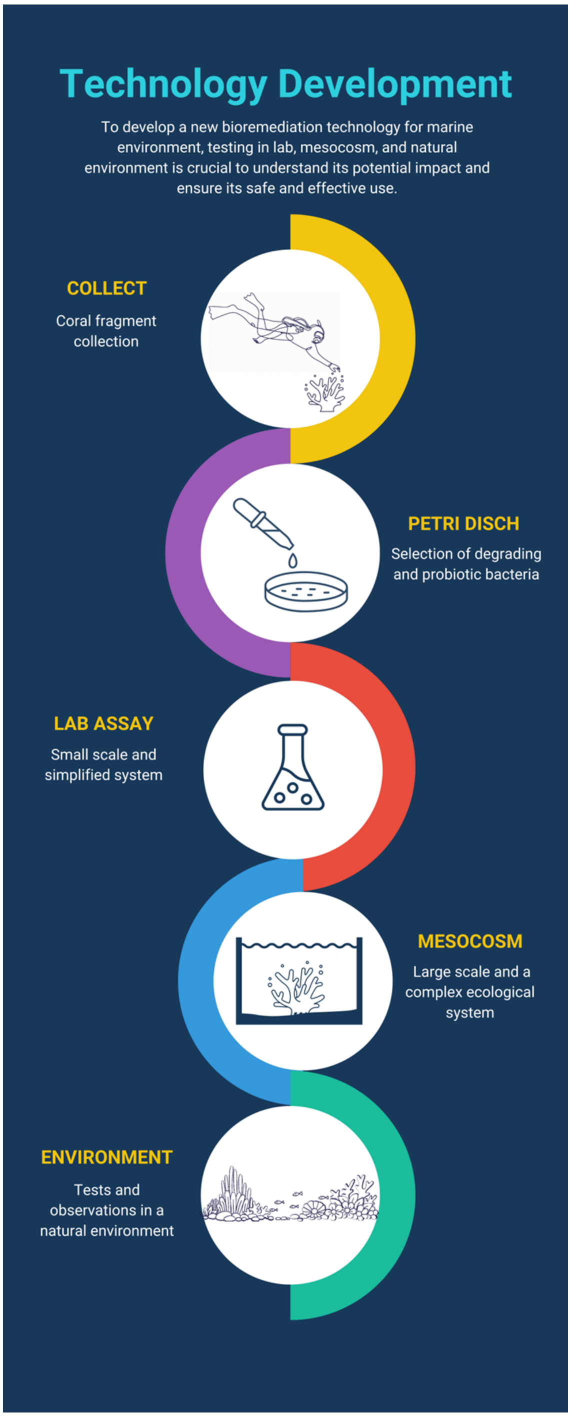

Figure 1: Schematic representation of microbial manipulation for bioremediation of coral reefs. The process involves the collection of coral samples followed by the isolation of petroleum-degrading and probiotic bacteria. Laboratory and mesocosm experiments are conducted to optimize the bioremediation process before application in field experiments. Field studies are critical for establishing the applicability and efficacy of bioremediation techniques in natural coral reef environments.

In conclusion, microbial manipulation shows great promise as a tool for enhancing bioremediation of coral reefs. However, further research is needed to optimize the selection and delivery of microbial species and to evaluate their long-term impact on the coral reef ecosystem. The development of effective microbial-based bioremediation strategies is crucial for the restoration and conservation of coral reefs, which are essential for the health and well-being of our planet

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