Study and Applications of Marine Microbes in Different Fields of Ecology

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Abstract: *The present study aims to highlight the microbial diversity of the oceans, covering over 70% of the planets surface. Occurrence of microorganisms is natural, and their place in human lives is growing pivotal. Marine microbes are sources of many bioactive compounds and also act as mediators in bioremediation prospect of various pollutants. The present study and futuristic approaches for application of these microbes will help understand marine habitat of microbes and open new dimensions in ecological studies.*

Key Words: *marine, pollutants, bioactive compounds, bioremediation*

1. INTRODUCTION:

Marine microorganisms are the dwellers of the oceanic waters and comprises of extensive and a diverse assortment of bacteria, virus, protists and fungi. Marine microorganisms exist, not only in the surface waters of the sea, but also in the lower and abyssal depths from coastal to the offshore regions, and from the general oceanic to the specialized niches like blue waters of coral reefs to black smokers of hot thermal vents on the sea floor including oceans, estuaries and lagoons, mangroves and coral reefs, the deep sea and the sea floor [1]. Prokaryotic organisms with bacterial r RNA and lipid membrane layers constitute the bacterial domain, while viruses having a size range of 20 – 200nm is about 10 to 100 times smaller than most bacteria with genetic material in the form or DNA or RNA. Although microorganisms are seldom perceivable in natural habitats, their contribution amounts to half the world's biomass [2]. Unlike plant and animal diversity, microbial melange is a strenuous area of research due to the diverse physiologic lifestyle and metabolic capabilities. The study of marine microbes has emerged from a couple of decades; however the finite and dispersed details in this area demand microbial taxonomy, which is quite meticulous and effortful. Microbial diversity is not only typological but it is more incorporating and comprehensive compared to plant and animal domain. Marine microbiota exists in the sea bed floor and helps in the nutrient cycling [3] as well as having immense potential in the production of enzymes, anti tumor compounds, and certain antibiotics. Evaluating microbial diversity is a formidable task, thus the importance and study of microbial ecology become demanding and captivating. Researches and experiments on microbial biodiversity will help in exploring different dimensions of marine microbes and futuristic use of their bioactive compounds.

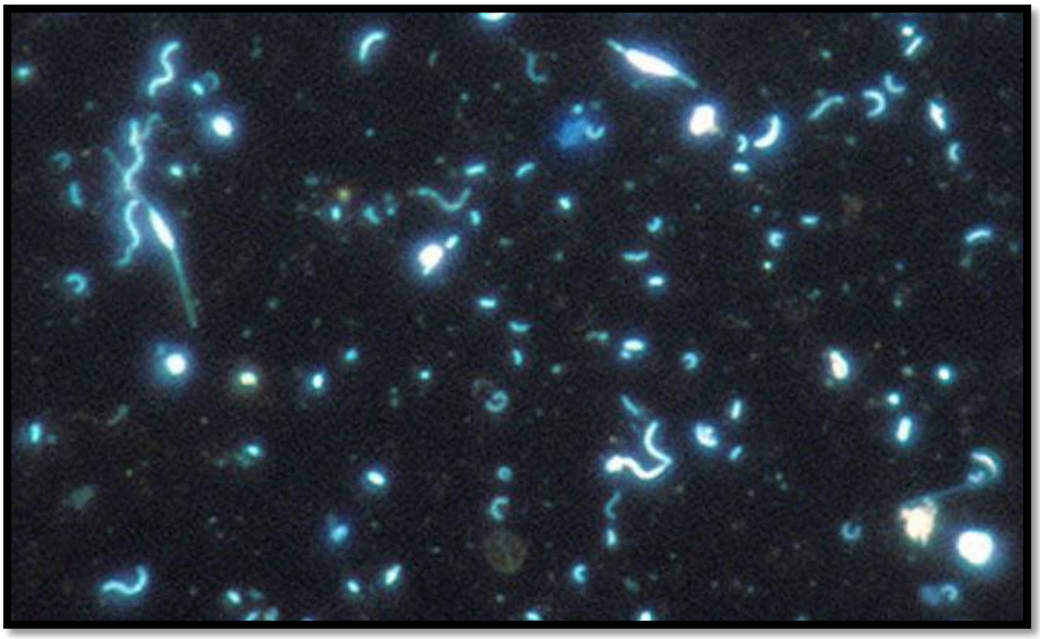

Fig 1. Amazing diversity of marine microbes. ***Photo Source courtesy***: (Ed DeLong / MBARI) **Monterey Bay Aquarium Research Institute (MBARI) and the Massachusetts Institute of Technology**

2. MARINE HABITAT:

Marine waters contain salinity ranging between 33 and 37 psu and can range in depth up to 11,000 m in the deepest of ocean benches (Mariana Trench). Oceans are divided into two zones: photic and aphotic. Light penetration up to a depth of 200 m, depends on the amount of turbidity in the water. Certain areas near the coasts receive low penetration of light < 1m, due to high levels of suspended particulate matter in the water. From a microbiological standpoint, four important habitats classify the marine environment based on habitats. At the surface, i.e. the air water interface, is referred to as the **neuston**, the water column or planktonic habitat is termed broadly as the **pelagic zone**, which is further subdivided on the basis of the depth of the water column. The habitat in the upper 100m of the water column is known as the epipelagic zone (i.e the photic zone). This zone comprises of mostly photosynthetic organisms. The benthopelagic zone (benthos) refers to a sea – sediment interface. The epibiotic habitat, is the third, which refers to surfaces on which attached communities occur. The fourth endobiotic habitat, pertains to organisms found within the tissues of other larger organisms such as fish. One such endobiotically living bacterium is *Vibrio fischeri*, which uses luminescence and quorum sensing in its unique lifestyle. The oceans contain diverse microbial habitats, which is highest in the neuston and significantly low below this region. Sea water contains huge numbers of microbes, although distant from human impacts, however, greater microbial concentrations may be found in the coastal areas. Numerous bacteria and **plankton** occur both at the surface and in deep ocean waters. Viruses require bacteria or other cells to prepare copies and for sheathing their genetic material. Scientific studies relate the presence of 10 to 100 million viruses in a teaspoonful of sea water.

3. MARINE ECOSYSTEMS:

Marine ecosystems form a realm for a myriad of different species ranging from planktonic organisms forming the base of the marine food web to large marine mammals. Different species recon marine ecosystems for food and shelter from predators. They are very important for the comprehensive overall health of both marine and terrestrial environments. Coastal habitats are those overlooking the spring high tide limit or above the mean water level in non-tidal waters [4]. Their closeness to the sea includes habitats such as coastal dunes, sandy shores, beaches, cliffs and supralittoral habitats. Approximately 30% of all marine biological productivity accounts, solely from coastal habitats. The assortment and productivity are also important for humans. These habitats dispense an extensive source of food and income. They also support species that serve as animal feed, fertilizers, additives in food and cosmetics. Mangroves and seagrasses are habitats, protecting the coastlines from wave action and erosion, while other areas provide sediment sinks or act as filtering systems. Increased human activities have kindled significant damage and pose serious threats to the marine biodiversity in spite of their known importance. These activities range from overfishing, pollution, introduction of exotic species or coastal development. Thus, certain steps for safeguarding and conservation of marine ecosystems should be taken in order to ensure safety and prevention of these ecosystems from being lost [5].

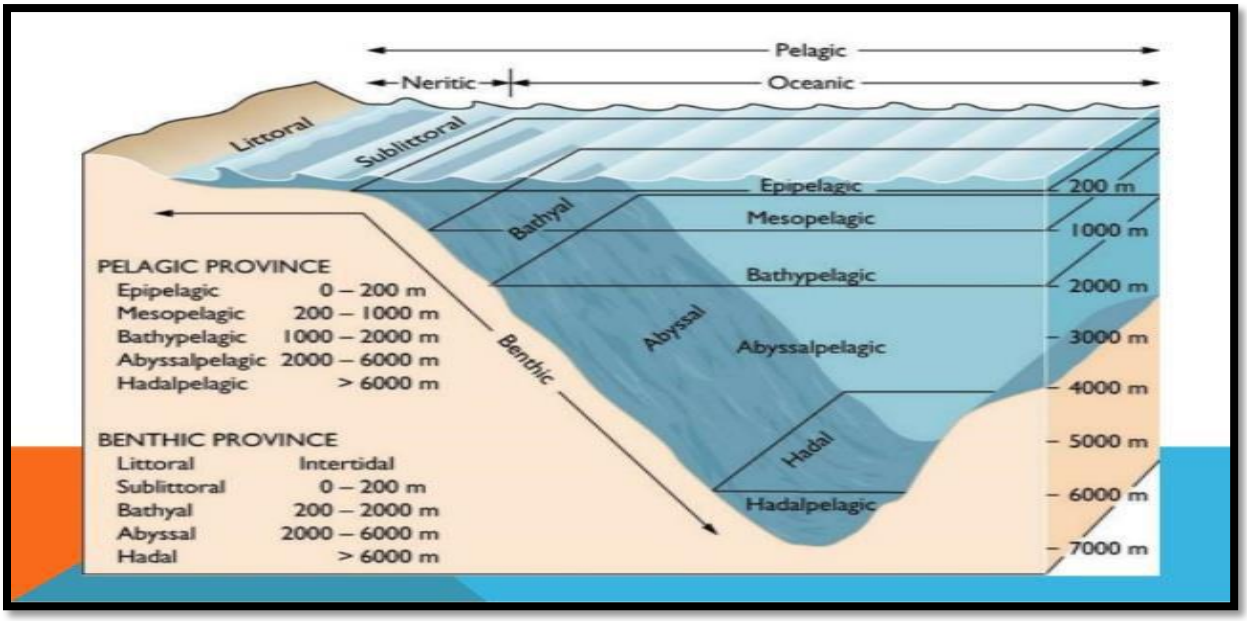

Fig 2 Zonation of marine ecosystem; Source: Biolulia European Sections

4. TYPES OF MARINE ECOSYSTEM AND RELATED MICROORGANISMS:

Ecosystem type	Properties	Applications		
		Bacteria	***Actinomycetes***	***Fungi***
Mangrove	An interface between terrestrial and marine environment	Helps in Photosynthesis [6] nitrogen fixation [7] methanogenesis [8] agarolysis [9] production of antibiotics and enzymes	Antibiotic-producing actinomycetes	Ideal environment for many detritus-dependent microbes [12]
Coral reef	Coral reefs are confined to shallow-water ecosystems, largely restricted to the seas. Marine organisms, which are collectively able to construct, modify or maintain the shore environment through the formation of limy (CaCO3) skeletons.	Supports high bacterial activity [10] Coral mucus consists mainly of polysaccharides and protein [11] and the mucus released from the corals serves as good growth substrates for bacteria.		
Deep sea	The deep sea is characterized a unique and extreme environment due to high pressure, low temperature, lack of light and variable salinity and oxygenconcentration.	Barotolerant bacteria from depths of 5000 m were recovered by Certes [13] and possible existence of such microorganisms in a state of suspended animation was also proposed.	Actinomycetes and other species isolated from this area are novel with potent sources of antibiotics. Colquhoun *et al*. [14] isolated mycolata actinomycetes from deep-sea sediments. An actinomycetes strain was isolated by Imada and Okami, [15] producing an inhibitory substance for beta-glucosidase.	Five species of indigenous deep-sea filamentous higher fungi: *Abyssomyces hydrozoicus*, *Allescheriella bathygena*, *Bathyascus vermisporus*, *Oceanitis scuticella* and *Periconia abyssa*. Raghukumar and Raghukumar [16] isolated barotolerant fungi *Aspergillus ustus* and *Graphium* sp. colonies from the Arabian Sea and Bay of Bengal, India.
Extreme environments	Environmental conditions that can comprehend beyond the normal acceptable range is regarded as an extreme condition [17]	Microorganisms inhabiting in such environments are termed as 'extremophiles'. The study of biodiversity on the edge explicates the relationships between organism and environment, and unravels the mechanisms of adaptation to extreme conditions [18].		Specifically, very little is known about the fungi living in the extreme environments. Biodiversity of fungal life decreases with increasing salt concentration.

Table 1 Different ecosystems and associated microbes.

5. ROLE OF MARINE MICROORGANISMS

- **As a source of food**

Low temperature, high salinity, absence of light and high pressure is characteristic features of the marine environment and heterotrophic bacteria are well adapted to them. Changes in water temperature, salinity and other physicochemical parameters [19] are important criteria on which these bacteria depend. Heterotrophic bacteria are the major components contributing to the oceanic microbial population and also help in the biological transformation of organic matter and the generation of carbon dioxide [20]. Thus; these bacteria not only serve as intermediates in biogeochemical processes, but also serve as an important food source for a variety of marine organisms and maintain an immaculate environment.

- **Utilization in the breakdown of organic matter**

Bacteria play a conclusive role in the breakdown of all organic matter into their original forms [21]. Some proteolytic bacteria such eubacteria and *pseudomonas sp*. help in the breakdown of proteins. Cellulolytic bacteria, such as *Cytophaga, Sporocytophaga* are responsible for cellulose decomposition [22]. Chitin, a structural polysaccharide is not degraded easily [23] as it is reported to be preserved in fossils [24] *Bacillus*, *Pseudomonas* and *Vibrio*, by the presence of their exoenzyme chitinase can degrade this biopolymer. *Clostridium pectinovorum* is known for the decomposition of pectin resulting in the end-products as pectic acid and methanol.

- **As sources of therapeutic enzymes**

Salt-tolerant, marine organisms provide a fascinating alternative for therapeutic purposes. The diverse range of enzymatic activity and catalysing ability for various biochemical reactions and novel enzymes, are characteristic feature of marine microorganism. Halophilic microorganisms contain hydrolytic enzymes, which can lead to precipitation of most of the proteins moreover saline sea water is closer to human blood plasma, and can produce microbial products specifically enzymes which are less toxic and have low or zero side effect when therapeutic application to humans are performed [25].

- **Production of Secondary metabolites and bioactive compounds**

Sophisticated chemical structures are common in secondary metabolites which are produced during the idiophase of microbial growth. A unique example of secondary metabolite is antibiotic production by marine bacteria which is uncommon in terrestrial microbes. Antibiotic production by marine bacteria was first studied by Rosenfeld and Zobell [26] and consequently many others have studied the same [27] [28]. An interesting area of bacteriological research is the study of antagonistic properties towards human pathogens, some of which are recently discovered and are MDR strains (Multi drug resistant) or already resistant to earlier discovered antibiotics [29]. The sea is a rich source of useful compounds with new chemical structures including significant immunomodulation, useful against allergy, anti-inflammatory and as a consequence, antitumor and analgesic, antibacterial and antiviral activities. A large proportion of active compounds, including fucoxanthin, astaxanthin, marine collagen peptides, dieckol, Krill oil and fucoidan, have been already researched to against metabolic dysfunction such as diabetes and obesity (Table 2). The effects of marine bioactive compounds when tested showed no toxicity and side effects. Marine bioactives have the potential to develop as functional food or drugs, as their biological activities appear to influence the pathogenesis and the clinical course of several metabolic diseases. Further research should be carried out in this area to disclose newer preventive and potential therapeutic strategies against metabolic dysfunction. Table 2, shows some bioactive compounds with their source and mechanism of action (Wang & Han, 2014 with modifications)

Different Bioactive Compounds

Compound	Source	Effect/Mechanism of action
Fucoxanthin	Kelp	Antidiabetic/Anti-obesity activity
Astaxanthin	Marine algae/ marine phytoplankton	Antidiabetic/ Anti-obesity activity
Marine collagen peptides	Deep-sea fish	Antidiabetic activity
Dieckol	*Ecklonia cava*	Antidiabetic/Anti-hyperlipidemic effect

Krill oil	Antarctic krill	Antidiabetic/ Anti-obesity activity
Fucoidan	*Laminaria sp.*	Antidiabetic/ Anti-obesity activity
Hyrtiosal	Marine sponge	Inhibit protein tyrosine phosphatase 1B (PTP1B) activity
SQA & SHQA	*Sargassum yezoense*	Reduce insulin resistance

Table 2. Bioactive compounds with their source and mechanism of action. Source: Wang & Han, (2014) with modifications [44]

6. ROLE OF MICROBES IN MARINE BIOGEOCHEMICAL CYCLES

Biogeochemical cycles refer to the movement and transfer of various chemical elements between several compartments comprising of living and non-living systems. Marine microbe's breakdown the complex compounds present in the marine and estuarine ecosystem. The cellulose present in the mangrove and associate vegetation (blue carbon) is broken to carbon dioxide (CO_2) by cellulolytic bacteria that are abundantly available in the intertidal mudflats. Nitrogen fixing blue green algae and denitrifying bacteria present in the marine and estuarine ecosystem play a critical role in regulating and maintaining the nitrogen balance in the atmosphere. The stability and proportions of different gases in the atmosphere are mostly regulated by marine microbes.

7. APPLICATION IN DRUGS AND PHARMACEUTICS

It is apprehended that oceans involve a huge number of natural products and novel chemical structures with unique biological activities useful in finding the prospective drugs with pronounced efficacy and specificity for the treatment of human diseases [30] pharmaceutical products such as novel anti-inflammatory agents (e.g., pseudopterosins, topsentins, scytonemin, and manoalide), anticancer agents (e.g., bryostatins, discodermolide, eleutherobin, and sarcodictyin), and antibiotics (e.g., marinone). The contribution of probiotic bacteria, such as *lactobacilli* and *bifidobacteria,* is mainly in the control of pathogenic microbes, through production of antibacterial protein namely, bacteriocin [31] [32] and anticancer substances [33]. The dietary supplements of *lactobacilli* are reportedly decreasing the induction of experimental colon cancer [34]. Most of the marine animal phyla produce toxins and some studies show that these marine toxins may be produced by marine bacteria associated the animals [35] [36]. The microbial toxins are useful in neurophysiological and neuropharmacological studies. For example, bacteria present in *Noctiluca scintillans* are responsible for causing red tides.

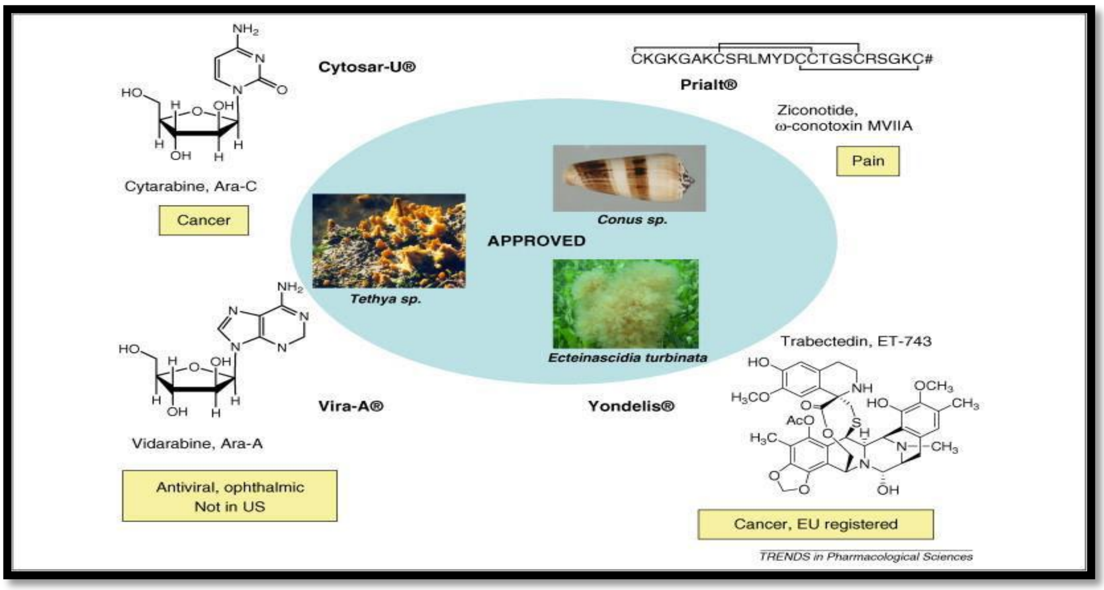

Fig: 3. Marine natural products or derivatives thereof approved for use by the FDA or EMEA, their biological source, chemical structures and treatment usage. Source: Newman et al; 2009. [43]

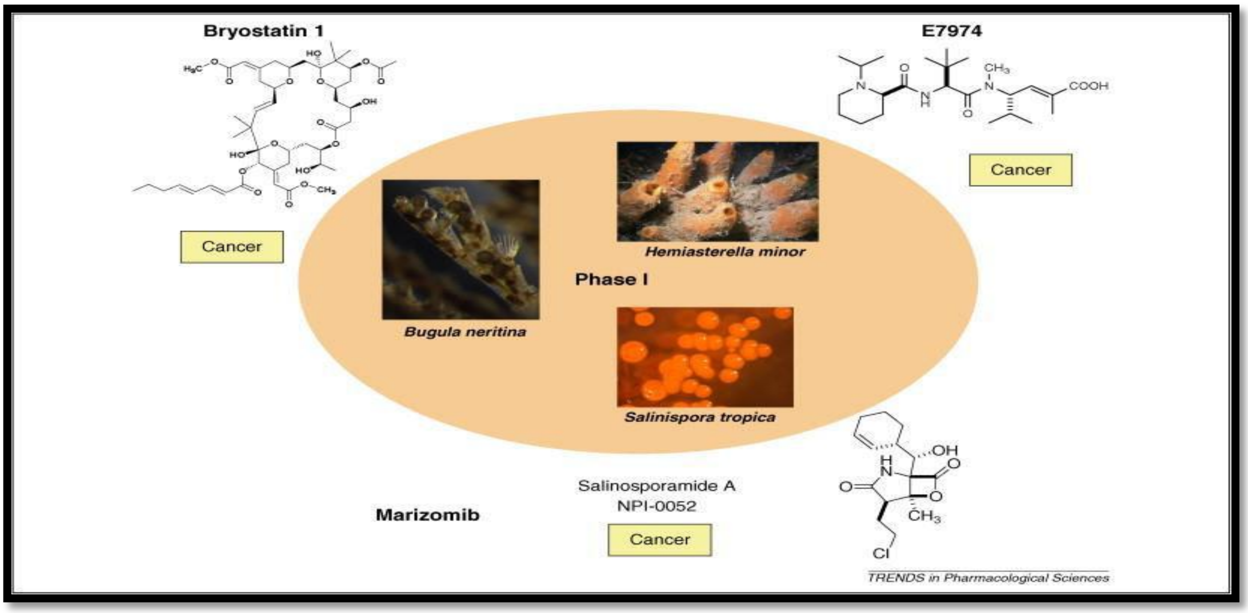

Fig 4. Marine natural products **Source:** Mayer, Alejandro M.S. et al. 2010 [42]

8. STATISTICAL APPROACHES TO STUDY MICROBIAL DIVERSITY:

One of the difficult areas of research, microbial diversity requires estimation, for proper understanding the biogeography, community assembly and certain ecological processes [37]. The number of species has been a conventional measure of biodiversity in ecology and conservation, is related to the number of species, but the biodiversity counts more than ‘species richness’ [38]. Statistical approaches can predict diversity which requires low sample sizes [39]. Hughes *et al.* [40] noted that both rarefaction and richness estimation applied to microbial datasets, emphasized the practicality of nonparametric estimators in the prediction and collation of bacterial species numbers. Operational taxonomic unit (OTU) definition, however remains reliable for rarefaction and richness estimation. The limitations of OTUs are that they are counted equivalently irrespective of divergent and phylogenetically unique, or closely related and phylogenetically redundant species [41].

9. CONCLUSION:

Biological diversity counts on proper conservation and utilization for which complete apprehension about the distribution of species is required to maintain ecological balance. Marine environments have witnessed anthropogenic involvement leading to threaten the lives of microorganisms. Marine microbiological studies are essential for understanding different practices of the ocean, leading to the evaluation of certain essential novel microorganisms for applications in the form of bioactive compounds. Complex ecosystems are characteristics of microbial institutions which can lead to extensive studies related to the role and distribution in their habitats. A combination of traditional and modern approach can be applied for better understanding of this vast and interesting domain.

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