Marine Bioprospecting: Novel Use of Ocean Resources

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ABSTRACT

Finding new biological products and activities in natural habitats that have potential biotechnological uses is known as "bioprospecting." Particularly, marine bioprospecting is a systematic search of marine organisms from the sea, along the coast, fjords, seabed, or oil reservoirs beneath the seabed. The process of marine bioprospecting involves search and discovery, beginning with the selection of appropriate environments and sampling methods based on previous information. It continues with the retrieval of biological materials and their proper storage, proceeds through screening for desired attributes such as microbial assemblages, cells, macromolecules, metabolites, or bioactive compounds using an ever-growing toolkit, and culminates in the development of commercial products or processes. This workflow represents a value-adding chain that ends with the addition of products and services responding to societal needs.

INTRODUCTION

Exploration of biological material for commercially valuable genetic and biochemical properties is known as Bioprospecting, also known as biodiversity prospecting. In simple terms, investigation of living things to see how they can be commercially useful to humans. It tends to be focused where biodiversity is at its richest such as regions at extreme depths in marine environment. Marine bioprospecting has been recognized worldwide for its enormous development potential, and its advancement is considered strategic not only for meeting key societal needs but also for economic growth. By harnessing the vast biological diversity of marine ecosystems, researchers and biotechnologists aim to unlock new sources of bioactive compounds and novel biotechnological processes that could revolutionize various industries. This interdisciplinary approach underscores the critical role of marine bioprospecting in driving innovation and fostering resilience in an ever-changing world.

Concepts of bioprospecting

Extreme environments, provide habitats for "extremophiles". The biological mechanisms and components that allow these extremophiles to endure high salinity, pressure, temperature, and other unique conditions. They are sources of great potential for scientific advancement and commercial application.

Example: *Thermus aquaticus* – Taq polymerase

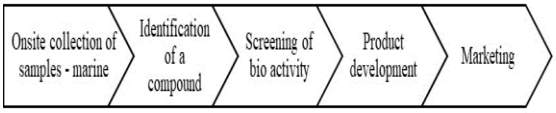
Antarctica ice fish – Anti freeze protein

Statistically, the chance of a successful "**hit**" of synthetic compounds - 1: 10,000 and of natural products - 1: 30,000

The aim of this concept is to

- Develop Anti-cancer agents
- Improve human health
- Drug development
- Finding new resource and products
- Biotechnology

Process of bioprospecting



From sample collecting on-site to product marketing, bioprospecting involves various steps

Pipeline of marine bioprospecting

Selection of products

Identify the organisms that synthesis the required substances by starting with a list of species.

Selection of marine organisms

Fungi, bacteria, (micro)algae, and other (rapid development, high bioactive chemical content, resilience to a range of stressors).

Selection of stress conditions

Environmental stressors (e.g., nitrogen, phosphorous, pH, salinity, metals, light, oxidative stress, temperature).

Mechanisms of products accumulation under stress conditions

Omics strategies (e.g., genomics, transcriptomics. lipidomics, glycomics, proteomics, metabolomics).

Selection of cultivation and storage modes

Selection of growth phase Two-stage, fed-batch or gradient strategies.

Identification of novel compounds

High value biochemicals (e.g., primary and secondary metabolites, biopolymers, proteins, enzymes) and their metabolic pathways.

- **Heterologous expression techniques:** Genetic transformation and genome editing methods for targeted bioactive compounds.

Screening of marine derived extracts

Screening for various purposes - medicine, cosmeceuticals, nutraceuticals, food, feed, agronomy and others.

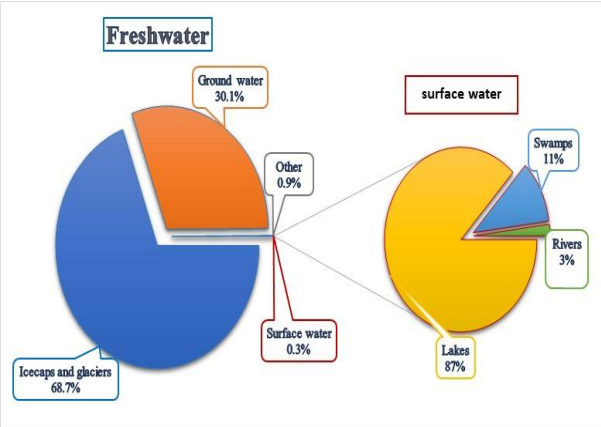
Exploring biological activities

Antioxidant, anti-cancer, anti-microbial, immunomodulatory activities, wound healing potential and more.

Marine Biotechnology

Marine biotechnology is the real chance to explore the marine biosphere and use nature's own technology to produce goods and services for the benefit of our society.

Distribution of Earth's water



Targets areas of research

- Biomedicine
- Cosmetic Applications
- Cosmetic Applications
- Human Consumption
- Education and Training
- Environmental New Processes
- Aquaculture
- Bioprospecting
- Nanotechnology
- Bioinformatics
- Genomics and Proteomics

Marine Bioprospecting

Systematic search in marine organisms from the sea, along the coast and from the fjords, from the seabed or from oil reservoirs beneath the seabed.

- A search for biomolecules from marine sources.
- A search for new and unique bioactive component with potential commercial application.

Marine Bioactive Compounds

Marine bioactive compounds are substances that are present in the marine environment and possess a range of characteristics, such as

antifungal, anticancer, antibiotic, and anti-quorum sensing.

How Bioactive compounds are produced?

The defence-attack signalling of organisms in biodiversity for competitiveness and survival under environmental stresses produces potentially novel medications with chemical diversity.

- The soft bodied and unmoved organisms are under threat with predators & environmental factors.
- To escape from the predators, they have to synthesize molecules with diverse of structures with potent biological activities.

Marine Rich Bioresource

From marine biodiversity, a variety of chemicals are extracted for use in microbiology, biofuels, nutraceuticals, cosmetics and medications. Microbiological investigations benefit from the usage of chemicals and enzymes, which are also obtained from the richness of marine life. Knowledge of sample collection from marine biodiversity, which serves as a source of novel products, is necessary to develop potential products.

Marine microbes

Having rich potential of antimicrobial active principles for protecting themselves from their predators. Due to the rich potential bioactive metabolites in the marine microbes, it may be used as drugs directly or used as lead structures for drug discovery. Now-a-days the antibiotic resistance and problems increased; alternative discovery needed.

Microbes associated with sponges

Association between sponges and bacteria produces secondary metabolites.

- More than 30 different phyla of Bacteria and Archaea as being associated with sponges.
- Bioactive metabolites originally isolated from sponges, were in fact synthesized or transformed by bacterial strains. There have been reports of bioactive chemicals with antimalarial, antibacterial, anti-HIV, antimicrobial, and antifungal effects being extracted from microorganisms associated with sponges.

Actinomycetes - An intermediate group between bacteria and fungi, abundantly present in the marine sediment. Example - *Streptomyces* sp., *Nocardiopsis* sp., *Marinispora* sp., *Salinispora* sp. and the culture- independent *Dietzia* sp. and *Rhodococcus* sp.

- Topmost producers of antibiotics @ 70%
- Major producers of antibacterial, antifungal, insecticidal, antitumor, anti-inflammatory, anti-parasitic, antiviral, antifouling and anti-infective compound.

Fungal Origin

Immense potential for new natural products. In hydrothermal sea ecosystem, unsuspected high diversity of fungal species identified with novel secondary metabolites recently. Vast source of diverse **antimicrobial 22** effective for Gram negative bacterial pathogens, HIV virus and fungus. Varixanthone, lunatin and xestodecalactone B are antibacterial and antifungal compounds derived from marine fungi (Punyasloke *et al*., 2006).

In vertebrate Resources

Group of animals have no backbone. In halobiotic environment, they have special adaptations, metabolic activities, secretions help to produce diverse of bioactive substances, protecting from harsh

environment. Among the invertebrates poriferans, cnidarians, annelids, arthropods, and molluscs have attracted attention due to antiviral, antimicrobial, antiprotozoal, anticancer, anthelminthic, antifungal bioactive compounds.

Porifera – Sponges

Most primitive metazoans Sessile filter feeders with efficient defense mechanisms against foreign attackers (viruses, bacteria or eukaryotes). Considered as gold mine during the past 50 years (>10000 compounds). Occasionally develop symbiotic relationship with algae and microbes. Topsentin, used in treating colon cancer extracted from *Spongosporites ruetzleri.*

Coelenterates

Cnidarians are the richest natural sources of prostaglandins. Jelly fish, sea nettle and sea anemones mostly secreted toxins with mixture of enzymes and polypeptides. Hydra, Jelly fish, coral & sea anemones produce bioactive compounds having anti-inflammatory, anticancer properties.

Annelids

Of the approximately 9000 species of annelids, > 8000 are polychaetes including lugworms, clam worms, bristleworms, fire worms, palolo worms, sea mice, featherduster worms, etc. They are found in most marine environments from tidal zones to hydrothermal vents having bioactive compounds used in several pathophysiological treatments such as arthritis, osteoporosis, and bone cancer.

Arthropods

Their bodies are segmented, they have jointed appendages (paired appendages), and they have an exoskeleton (external shell). From marine arthropods such as horseshoe crabs, crabs, krill, and shrimps, a number of bioactive chemicals have also been identified. Krill oil and enzyme extracted from tiny shrimp, Antarctic krill (*Euphausia superba*), is a species of krill found in the Antarctic waters of the Southern Ocean is a food for whale having extractable amounts of Omega 3 fatty acids, especially EPA and DHA which reduces the risk of heart disease, reduce high cholesterol, high blood pressure, stroke, cancer, osteoarthritis, depression.

Shell waste of arthropods contain chitin - a high molecular weight polymer N-acetyl-D-glucosamine with biomedical applications. A heteropolymer, chitosan is produced when chitin is deacetylated. Reducing LDL, antioxidants & anticancer, immunostimulants, DNA vaccine delivery, biopesticide-agricultural are the uses found with these compounds. Percentages of chitin in clam/oyster (3-6%), crab (13.5-26.6%), shrimp (17-40.4%), crawfish (29.8%), prawn (33%), squid pen (20-40%), krill (41%) are found on dry weight basis (Synowiecki, J. *et al*., 2006). Regenerative effect on connective gum tissue, accelerates the formation of osteoblast responsible for bone formation, accelerates bone formation, haemostatic, spermicidal, antitumour, anticholesteremic, CNS depressant, immunoadjuvant are the properties and applications of chitin and chitosan.

Mollusca

Largest marine phylum, comprising about 23% of all the named marine organisms. Example-Snails, octopuses, squid, clams, scallops, oysters, and chitons. Also important to humans - as a source of food, jewelery, tools, and even pets. Dolastin (Sea slug) - anticancer activity. Arctic surf clam (*Spisula polynyma*) – anti-proliferative & anti-cancer. Green mussel extract (*Perna viridis*)-arthritis: anti-inflammatory, are some of the mollusc derived compounds.

Fish and other vertebrates

There are few metabolites recovered from fish, aquatic animals, and sea snakes (hydrophidae). Omega-3 fatty acid-rich fish oil has several therapeutic uses. 500 species of fish are considered toxic (Tetradotoxin (TTX), used as bio active compound. Squalamines are water-soluble antibiotics derived from the *Squalus acanthias*, dogfish shark. "Fu- anntai", an anti-cancerous drug from sea snake.

Fish Oil (Cod Liver oil)

Rich in Omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and vitamins. Fish oil having Safety and potential nutritional and therapeutic effects. Good for Heart health, Liver tonic, antioxidant & cure cancers. Good for health, Good for Eye, Anti-stress compound.

Shark Fin Cartilage and Rays

Shark Fin Soup

Some regions of Southeast and China serve "shark fin soup," which is a stewed meal or soup prepared with fish fins. Boost sexual potency, enhance skin quality, prevent heart disease, lower cholesterol, beneficial to lung & kidney are the properties of the shark fin soup.

Shark Bone cartilage

Prevent variety of illness, property of angiogenesis, prevent cancer. Other medical conditions for which shark cartilage is utilized include psoriasis, arthritis, wound healing, diabetic retinal impairment, and intestinal inflammation (enteritis).

The Chinese have traditionally treasured shark cartilage (Shark fin soup). A series of complex carbohydrates called mucopolysaccharides, which contains the now-famous chondroitin sulfate, are present in shark cartilage. An excellent source of calcium and phosphorus. Although many clinical trials were unable to show any symptomatic effect of chondroitin, chondroitin sulfate has become a popular dietary supplement for the treatment of osteoarthritis.

Fish Bone and Collagen

Fish Collagen

Structural protein in connective tissue. Used in cosmetic, biomedical, pharmaceutical, leather and film industries.

Fish Bone

Contains 60-70% of inorganic substances & rich in calcium. Essential elements for human health. Solve the problems related to bone.

Algae

Algae have a tremendous impact on the sustainability of the marine ecosystem as being the primary producers and, therefore, a food source for other marine organisms. Microalgae synthesize bioactive molecules such as pigments and lipids that exhibit health properties. *Chlorella* and *euglena* grown in photo bioreactor is used to produce oxygen in space for astronauts. Algae as production of biodiesel, algal biofuel contains no Sulphur, non-toxic and highly biodegradable.

Seaweed extracts

Alginate - Isolated from Brown seaweed. Used as emulsifier in food industries.

Carrageenan - Isolated from Red Sea weeds, powerful antioxidant, broad range of applications in food and cosmetics.

Laminarian - Isolated from Brown Sea weeds, regulator of intestinal metabolism, tumour-inhibiting agent, antibacterial agent, protection against severe irradiation, boosting the immune system, reduces cholesterol levels in serum.

Merits of Bioprospecting

- Discovering new drugs and sustainable exploration of aquatic diversity.
- Economic viability of marine bioresources for pharmaceutical purposes.
- Invention of several lifesaving drugs.
- Traditional culture and habitats are preserved by re-discovering ancient native practices.
- The collaboration between many pharmaceuticals companies and countries supplying the medicinal raw material and knowledge offer the revenue source.
- Having scope for benefiting pharmaceutical industries, as well as native country and indigenous communities.

Limitations of Bioprospecting

- A time-consuming process and no certainty of returns.
- Capital intensive is very high.
- Methods of deriving compounds are somewhat risky.
- Genetic material imbalance in the ecosystem.
- Unsustainable harvesting and other negative environmental impacts may damage the biodiversity and environment.
- Imbalance in ecosystem due to excessive exploitation of material resources.

Marine Bio-prospecting Policy

Bioprospecting should be regulated, both at the national and international level, based on the principles of the - Convention on Biological Diversity, Conservation of biodiversity, Sustainable use of its components, Fair and equitable sharing of the benefits by utilization of genetic resources.

Various legal instruments and organizations related to coastal genetic resources

Convention on Biological Diversity (CBD) - The Convention on Biological Diversity (CBD), chairing 196 nations has come up with international guidelines for the equitable and fair distribution of the benefits resulting from the use of genetic resources for the sustainable use and conservation of biological diversity and its constituent parts.

Bonn guidelines and Nagoya Protocol - A voluntary set of rules known as the Bonn rules aids governments and other relevant parties in creating access and benefit-sharing (ABS) plans and Nagoya Protocol is an international agreement that attempts to share the advantages deriving from the usage of genetic resources in a fair and equitable manner. The rules were approved in 2002 by the Conference of the Parties to the Convention on Biological Diversity (CBD).

United Nations Convention on the Law of the Seas (UNCLOS) - An international treaty known as the United Nations Convention on the Law of the Sea (UNCLOS) sets guidelines for the usage of the oceans and seas around the world. In 1982, it was ratified.

International Seabed Authority - The International Seabed Authority (ISA), an independent international organization created by the United Nations Convention on the Law of the Sea (UNCLOS) of 1982 and the 1994 Agreement relating to the Implementation of Part XI of the UNCLOS.

Global Ocean Commission - The Global Ocean Commission was an international effort that ran from 2013 to 2016 with the goals of addressing ocean degradation, promoting action to stop it, and assisting in the restoration of the ocean to its full health and production.

The vast oceanic regions that lay outside each state's Exclusive Economic Zone were the main focus of the study.

European Science Foundation - With 11 member organizations committed to scientific research in 8 European nations, the European Science Foundation (ESF) is an association.

Valencia Declaration - Lays forth a strategy for enhancing UN Maps-based geospatial information exchange and coordination systems inside the organization.

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