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Marine Biotechnology and Blue Economy

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Content

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Introduction

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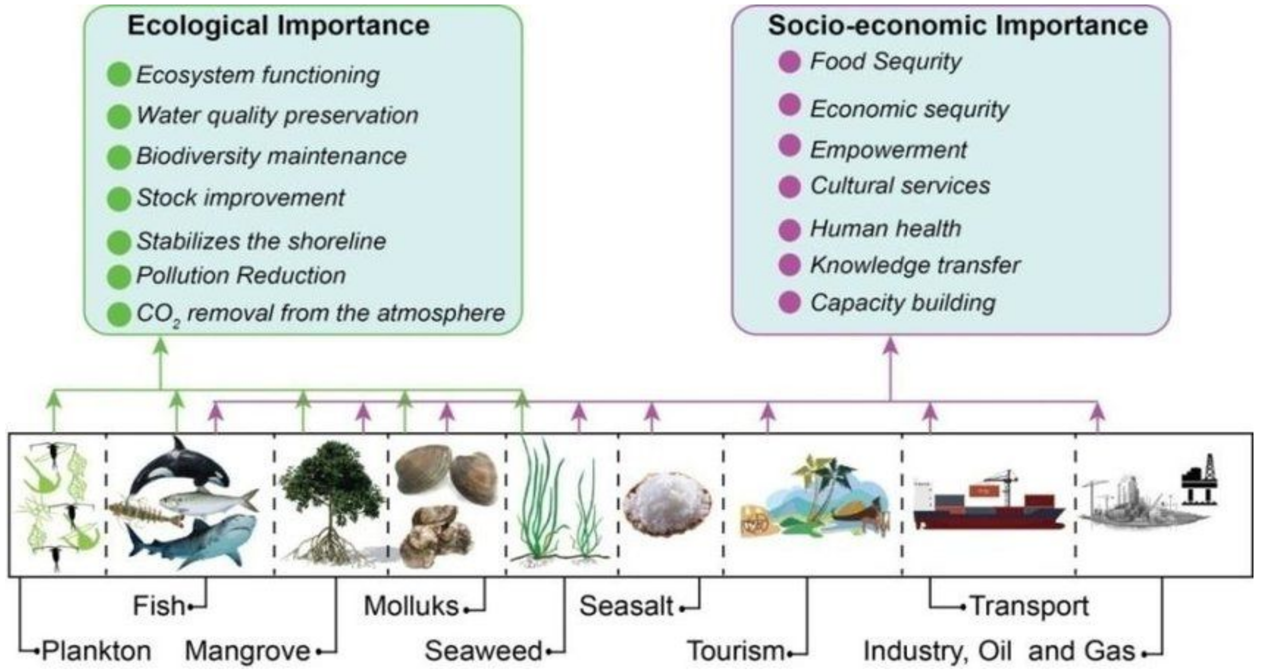
Technological advancements in *marine biotechnology* have expanded the bioprospecting of marine organisms. However, this progress has also been accompanied by the exploitation of marine resources, which in turn harms marine ecosystem (Zhong, 2019; Cristina, 2022).



(Hussain dkk., 2019)


(Ambari,2019; Chias 2019; Deep Ocean Education)

14 LIFE BELOW WATER

Sustainable solutions are needed in the utilization of marine resources that both improve human well-being and preserve ecological balance (Okafor-Yarwood et al., 2020).

Blue Economy concept
- Economy
- Social
- Ecology

utilizing marine resources in a way that contributes to sustainable economic growth while maintaining ocean health (Hussain et al., 2019).

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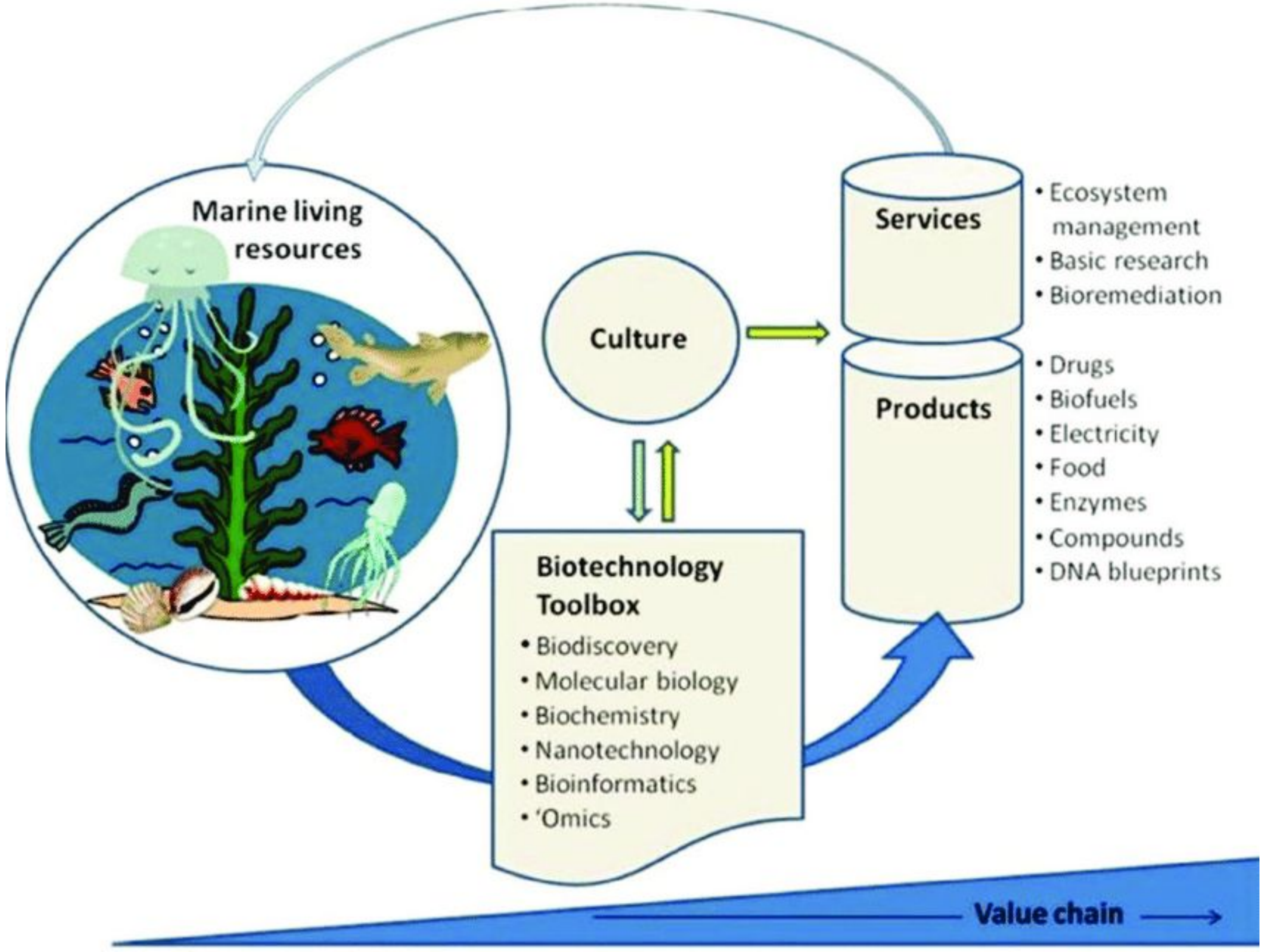
The role of marine biotechnology in enhancing blue economy sectors

Marine Biotechnology

- Utilizing technical and scientific concepts to process materials using marine biological organisms in order to produce commodities and services (Zilinskas et al., 1995).
- **Applications :** health, food, cosmetics, aquaculture & agriculture, fisheries, manufacturing, environmental remediation, biofilms and corrosion, biomaterials, research tools, etc. (Cristina, 2022).
- **Techniques :** bioprocessing, bioharvesting, bioprospecting, bioremediation, using bioreactors, etc. (Cristina, 2022).



(OECD, 2013)

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The role of marine biotechnology in enhancing blue economy sectors

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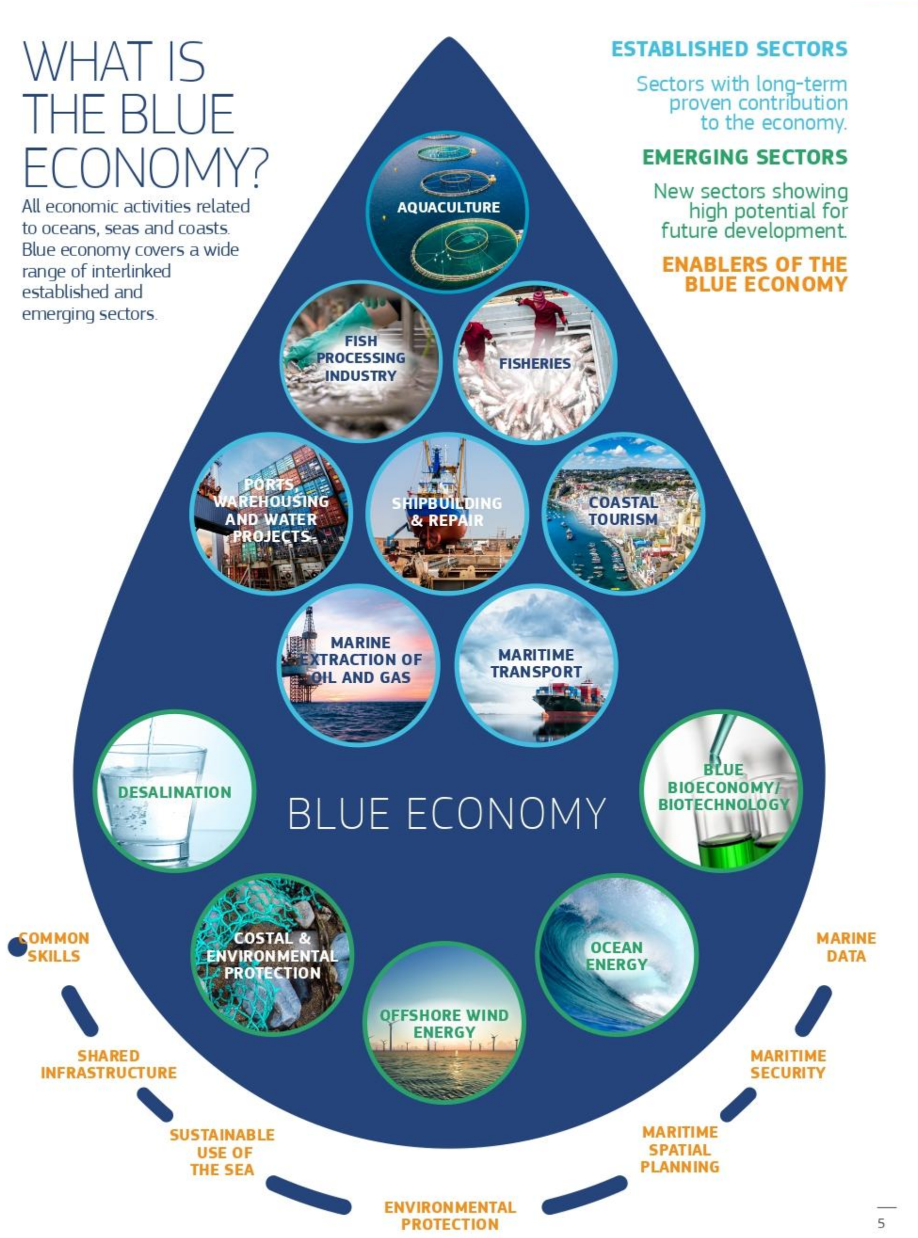
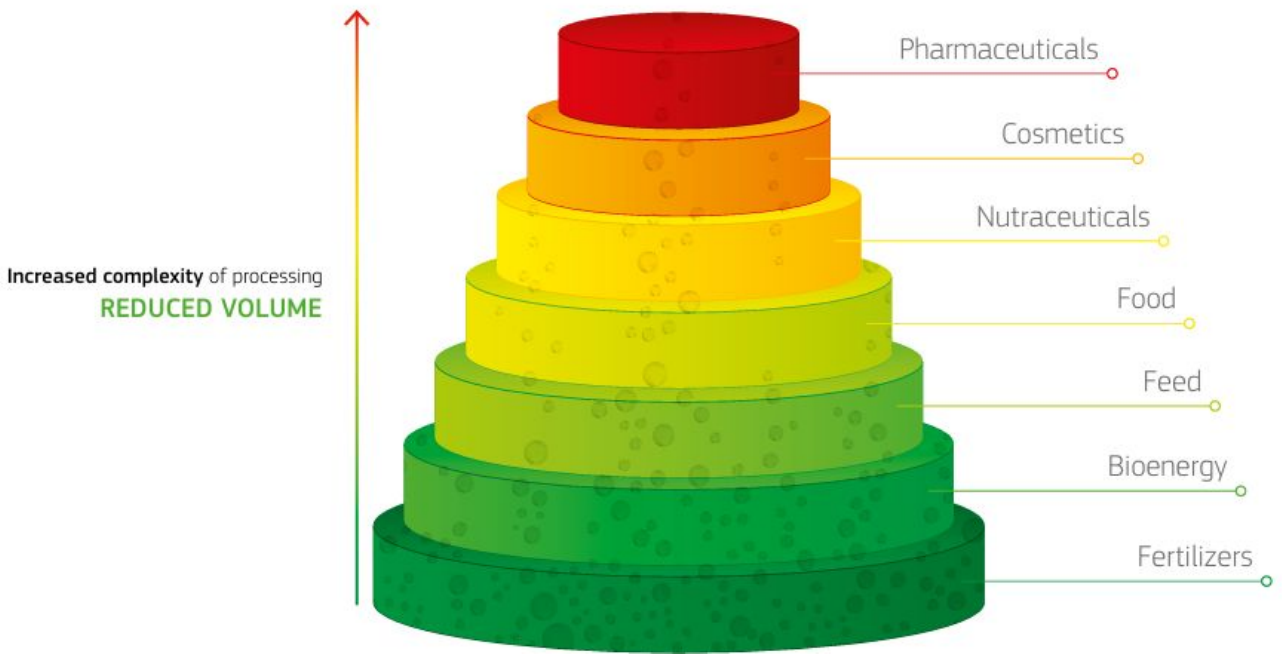
<u>Blue Economy</u>

Ocean economy that aims the improvement of human well-being and social equity, while significantly reducing environmental risks and ecological scarcities (Bari, 2017).





Products	Time to market (Years)	Cost of development	Resource availability	Need for documentation	Potential market value	Skills and competencies
Pharmaceuticals	10 – 15+	Very high	Limited	Very high	Very high	Extensive medical and market
Cosmetics	3 – 5 +	Low to high	Fair	Medium	High	Toxicology, effects
Nutraceuticals	3 – 5 +	Medium to high	Fair	Medium to high	High	Nutrition and medicine
Food	2 – 5 +	Low to medium	Good	Medium	Medium to high	Nutrition, food science
Feed	2 – 5 +	Low to medium	Very good	Medium	Medium to high	Nutrition, animal science
Bioenergy	2 – 5 +	Low to medium	Very good	Low to medium	Moderate	Energy
Fertilizers	1 – 2	Low	Very good	Low to medium	Moderate	Agriculture, agronomy etc

(OECD, 2013)

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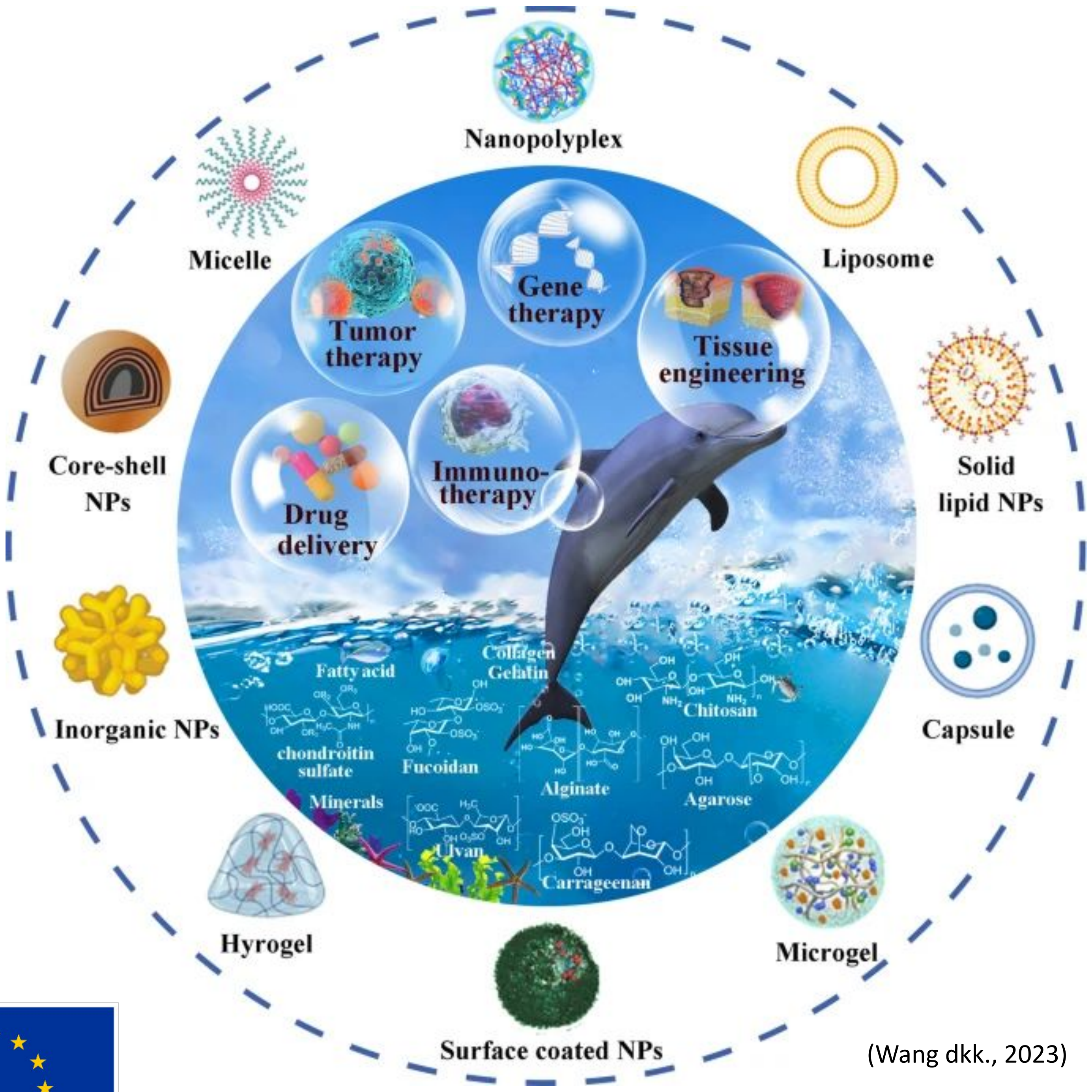
Application of Marine Resources beyond Food: Biomaterial



(Wang dkk., 2023)

- The unique environmental characteristics of marine ecosystems result in the structure, composition, and biological activity of polysaccharides in marine organisms that differ from those in terrestrial organisms.
- These materials primarily play a role in biomedicine offering antitumor, antibacterial, antioxidant, anti-inflammatory, immunomodulatory, and cardioprotective effects.
- In addition, they also contribute to enhancing cell migration, cell-matrix interactions, and tissue regeneration.

(Wang et al., 2023)

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Application of Marine Resources beyond Food: Biomaterial

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Types of biomaterials, chemical structure, sources, and its applications (Zhang et al., 2022)

Type	Chemical structure	Sumber	Kegunaan
Chitin dan chitosan	Polysaccharide (β-1,4-glucosamine)	Exoskeletons of crustaceans (shrimp and crabs), marine fungi, algae, and lower plants	Anti-inflammatory, hemostatic, tissue regeneration, *drug delivery material*, anticancer
Alginate	Polysaccharide (mannuronate & guluronate)	Brown algae (kelp, sargassum) and some marine bacteria (*Azotobacter*, *Pseudomonas*)	Tissue gel, drug carrier, scaffold for tissue engineering
Carrageenan	Sulfated polysaccharide (galactose)	Red algae (*Eucheuma, Hypnea,* and *Chondrus*)	Antiviral (including SARS-CoV-2), antibacterial, drug delivery material
Fucoidan	Complex sulfated polysaccharide (fucose)	Brown algae (Fucales: *Fucus, Laminaria*) and marine invertebrates (sea cucumber, sea urchin)	Antitumor, imunomodulator, anticoagulant, antiviral
Ulvan	Sulfated polysaccharide	Green algae (*Ulva* spp.)	Anticoagulant, immunomodulator, antioxidant, anti-inflammatory

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Application of Marine Resources beyond Food: Biomaterial

(continues)

Type	Chemical structure	Source	Application
Laminarin	β-glucan	Brown algae (*Laminaria, Saccharina*)	Antitumor, antioxidant, anti-inflammatory, prebiotic
Hyaluronic Acid (HA)	Glycosaminoglycan (GlcA & GlcNAc)	Connective tissues of marine animals (skin, head, or fish scale)	Tissue lubricant, anti-inflammatory, extracellular matrix
Chondroitin Sulfate (CS)	Glycosaminoglycan (GlcA & FalNAc)	Cartilage, eyes, liver, and fish scales	Cartilage regeneration, anti-inflammatory, immunomodulator
Collagen	Fibrillar protein (triple-helix collagen)	Fish (skin, fins, cartilage), marine sponges, jellyfish, sea cucumber	Tissue scaffold, wound dressing, drug capsules, tissue engineering

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Application of Marine Resources beyond Food: Cosmetics

The utilization of marine resources into secondary products such as cosmetics supports SDG 14 by creating sustainable (*zero waste policies*) (Siahaan et al., 2022).

(Siahaan dkk., 2022)

- Cosmetics are substances or mixtures used on the external parts of the body, teeth, or mucous membranes of the oral cavity to cleanse and care for the body. Cosmetic products made from natural ingredients contain various chemical compounds that enhance their specificity and functional efficiency (Fonseca dkk., 2023)
- Marine resources used as cosmetic ingredients have the potential to act as antioxidants, provide anti-aging effects, and help prevent wrinkles and acne (Rotter dkk., 2024).

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Application of Marine Resources beyond Food: Cosmetics

Type of cosmetics made from marine resources (Rotter dkk., 2024)

Type	Main composition	Function/Utility	Product examples
Macroalgae	Polysaccharides (alginate, carrageenan, fucoidan), pigments, antioxidants	Anti-inflammatory, anti-aging, moisturizer, UV-protection	Anti-aging cream, lotion, facial mask
Microalgae	Pigments (carotenoids, astaxanthin), lipids, bioactive proteins	Strong antioxidants, protection of skin from free radicals, natural colorants	Cosmetic active ingredients, biopharmaceutical supplements
Marine sponges	Secondary metabolites (terpenoids, alkaloids, cyclic peptides)	Antibacterial, anticancer, high bioactivity	Cosmetic active, ingredients, pharmaceutical supplements
Soft coral & Cnidaria	Collagen proteins, anti-inflammatory substances	Cell regeneration, skin smoothing, anti-aging	Marine collagen products, skin serums
Mollusca and Crustaceans	Chitin and chitosan	Carrier agent of active ingredients, moisturizers, film-forming angents	Patch transdermal, moisturizers
Fish and its by-products (fins, scales, etc.)	Collagen proteins, bioactive peptides	Antioxidants, skin tissue formation, wrinkle prevention	Fish collagen cream, functional collagen drinks

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Application of Marine Resources beyond Food: Drugs

Utilization of marine resources as medicines (Gupta dkk., 2023).

Function	Marine organism	Bioactive compound	Product/Application
Anticancer	Marine sponge (*Tethya crypta*)	Cytarabine	Leukemia drug, inhibits DNA replication
	Tunicate (*Ecteinascidia turbinata*)	Trabectedin (ET-743)	Chemotherapy for soft tissue sarcoma
	Bryozoa (*Bugula neritina*)	Bryostatin	Research in leukemia & Alzheimer's therapy
	Marine sponge (*Halichondria*)	Eribulin (Halichondrin B analog)	Metastatic breast cancer drug
	Sea snail (*Dolabella auricularia*)	Dolastatin 10 (Soblidotin derivative)	Antitumor drug, inhibits cell division
Antiviral	Marine sponge (*Tethya crypta*)	Vidarabine (Ara-A)	Herpes drugs (HSV-1, HSV-2), used for eye infections
	Marine sponge (*Celtodoryx girardae*)	Exopolysaccharides (EPS)	Antiviral activity against HSV-1

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Application of Marine Resources beyond Food: Drugs

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(continues)

Function	Marine organism	Bioactive compound	Product/Application
Analgesic (pain relief)	Sea snail (*Conus magus*)	Ziconotide (conotoxin MVIIA)	Non-opioid chronic pain reliever, injected into spinal fluid
Neuroprotective	Green algae (*Ulva reticulata*)	AChE & BChE inhibitors	Potential Alzheimer's & neurodegeneration therapy
Anti-inflammatory	Marine sponge (*Spongia officinalis.*)	Anti-inflammatory compounds	Pre-clinical tests for reducing inflammation
Anti-parasitic	Marine sponge (*Sarcotragus* sp.)	Bioactive extract	Targets *Leishmania major*, leishmaniasis therapy
Antibacterial/antimicrobial	Diatom (*Phaeodactylum tricornutum*)	Eicosapentaenoic acid (EPA, omega-3)	Supplements, anti-inflammatory, antimicrobial effects
	Marine fungi (*Acremonium* sp.)	Cephalosporin C	β-lactam antibiotics, precursor to modern cephalosporins
Neurotoxin (experimental)	Pufferfish (*Tetraodontidae*)	Tetrodotoxin (TTX)	Studied for local anesthesia and neurotoxicology modulation

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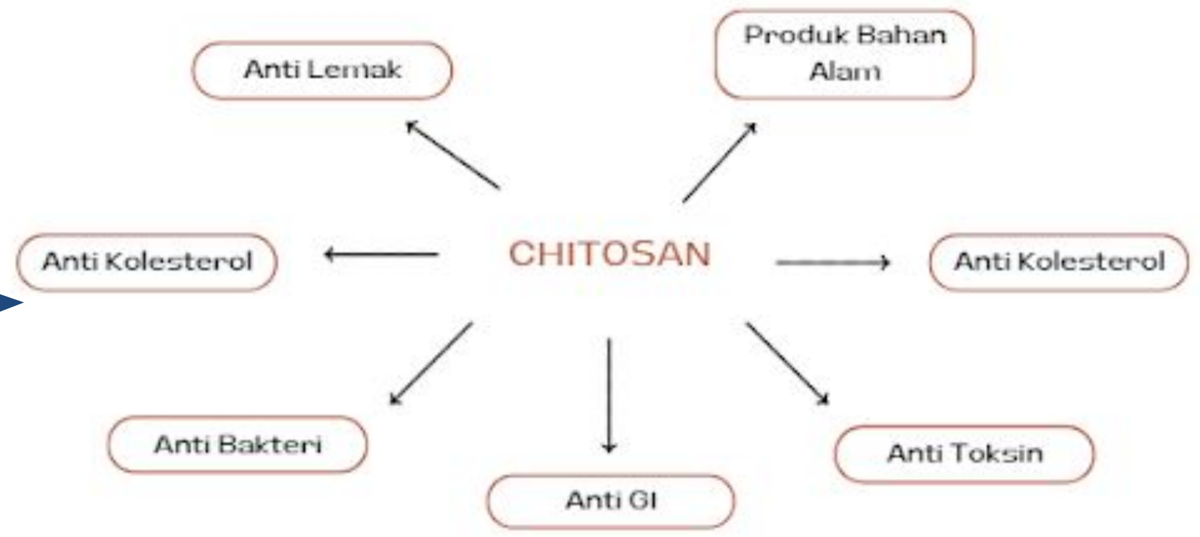
Case example:
From Crustacean shell waste to RAMAMBU

(Google Earth)

(Tribun Jateng)



(Lestari et al., 2024)

Banyubiru Village, Pandeglang, Indonesia has abundant **marine and coastal resources**. One local issue is the **organic waste from crustacean shells** (shrimp, crab) which it contributes to environmental pollution and health risks in nearby livestock farms. However, **crustacean shells contain chitosan**, a biodegradable and biocompatible compound with multiple benefits. These properties offer a sustainable approach to managing crustacean shell waste (Lestari et al., 2024).

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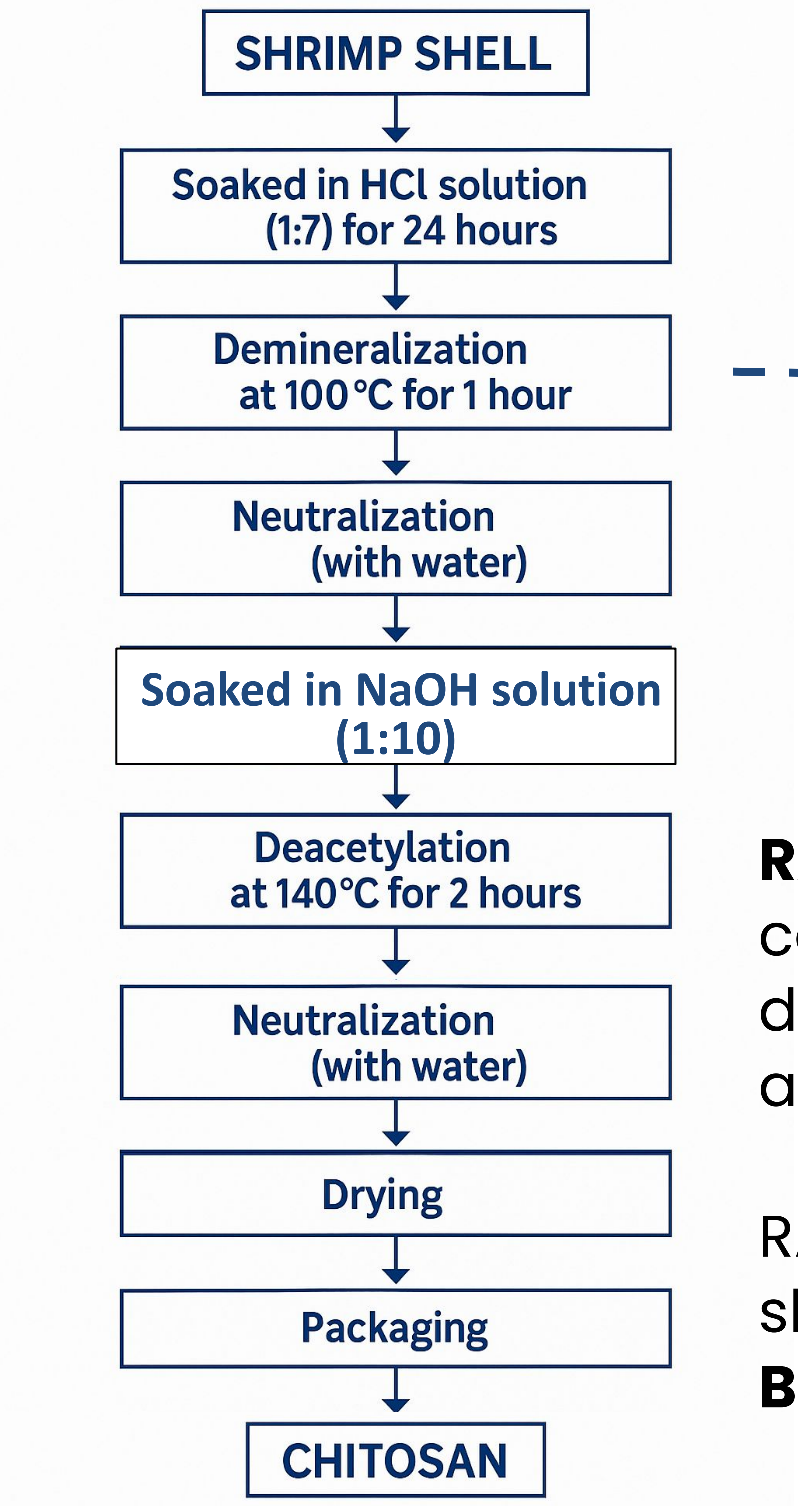
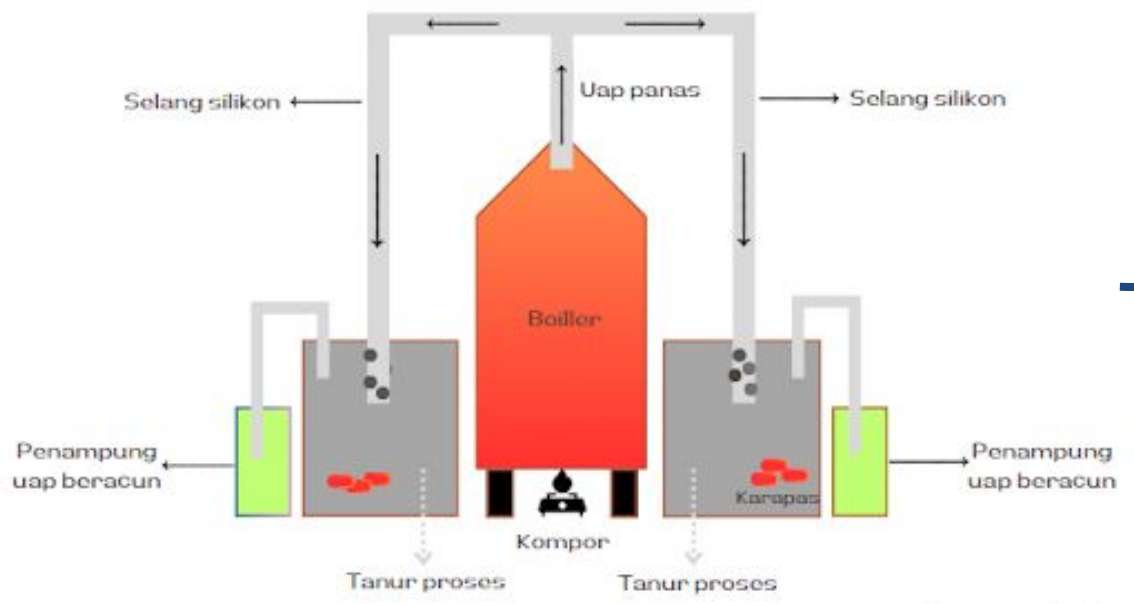
Case example:
From Crustacean shell waste to RAMAMBU





RAMAMBU

RAMAMBU is an organic-based disinfectant developed by a university collaboration team (UI, UNTIRTA, and Mathla'ul Anwar University), **using chitosan** derived from crustacean shells to eliminate odors and prevent disease (Lestari et al., 2024).

RAMAMBU offers **a sustainable economic solution** by transforming crustacean shell waste into **valuable products through marine biotechnology, aligning with Blue Economy goals** (Lestari et al., 2024).

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Brief discussion:
Algae Biofuels as Renewable Marine-Based Bioenergy

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(Green City Times)

Why Algae Biofuels?

(Neti dkk., 2023)

Advantage	Description
Carbon neutral	Conversely, algae absorb CO_2 during growth which balances out any CO_2 released during combustion.
High productivity	Algae are an attractive biofuel crop due to its fast growth rate and high biomass output per unit area.
No competition with food crops	Algae are not a competition to food crops.
Potential for sustainable production	Algae can be grown safely and sustainably within an enclosed system (photobioreactor), eliminating contamination risk while simultaneously supporting sustainable production.
Versatility	Algae can produce biodiesel, bioethanol, biohydrogen, and bio-oil as by-products from their fermentation. Biogas production also depends on algae for power.
Waste reduction	Algae can be grown using wastewater or carbon dioxide emissions from industrial processes, reducing pollution and waste while decreasing pollution levels.

Analyze:

- Do you think algae biofuels are a better alternative than fossil fuels? Why or why not? Compare their advantages and limitations.
- What is the biggest technological challenge in producing algae biofuels on a large scale, and what could be potential solutions?

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Conclusion

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- Marine biotechnology plays a crucial role in strengthening the sectors of the Blue Economy through innovative products derived from marine organisms.
- Applications such as biomaterials, cosmetics, and pharmaceuticals from marine resources demonstrate great potential to support sustainable development. However, the exploration of marine resources must be carried out carefully and in a controlled manner to avoid harming ecosystems.
- An interdisciplinary approach and collaboration between science, society, and policy maker are key to optimizing the benefits of marine biotechnology within the framework of the Blue Economy.

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