Pharmacogn. Res., 2025; 17(3):697-706.
https://www.phcogres.com

Review Article

Natural Marine Species Bioactive Compounds and their Ethnopharmacological Approach from Ecological Biodiversity: Sustainable Therapeutic Properties

Paramita Ganguly[1], Puja Saha[2], Sandip Chatterjee[3,*], Prangya Paramita Pati[4]

[1]Department of Pharmaceutical Technology, Brainware University, Barasat, Kolkata, West Bengal, INDIA.
[2]Department of Pharmaceutics, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, INDIA.
[3]Narayan Institute of Pharmacy, Gopal Narayan Singh University, Jamuhar, Sasaram, Rohtas, Bihar, INDIA.
[4]Department of Pharmacognosy, Gayatri College of Pharmacy, Sambalpur, Odisha, INDIA.

ABSTRACT

Marine ecosystems are a rich source of bioactive compounds, offering immense potential for therapeutic applications. Research studies from pubmed, Google scholar, Science direct, databases provided derived from diverse organisms such as algae, sponges, mollusks, and marine microorganisms, these natural products exhibit a wide range of pharmacological properties, including antimicrobial, anti-inflammatory, antioxidant, and anticancer activities. Ethnopharmacological knowledge, deeply rooted in traditional practices, serves as a valuable guide for identifying the medicinal potential of marine resources, creating a bridge between traditional wisdom and modern drug discovery. Recent advancements in biotechnological tools and sustainable bioprospecting have accelerated the discovery, isolation, and development of these bioactive compounds into promising therapeutic agents. Despite these advancements, significant challenges remain. The exploration of marine biodiversity is still limited, with many ecosystems, such as deep-sea and polar regions, largely unexplored. Sustainable harvesting practices, understanding the mechanisms of action and pharmacokinetics of marine bioactive, and mitigating the environmental impacts of large-scale extraction are critical issues. Additionally, the integration of ethnopharmacological knowledge with modern scientific approaches requires systematic validation and documentation. This review emphasizes the therapeutic potential of marine bioactive compounds, highlights the importance of sustainable and ethical bioprospecting practices, and identifies key research gaps that must be addressed to fully harness the benefits of marine biodiversity for global health.

Keywords: Ethnopharmacology, Marine organism, Marine drugs, Biodiversity, Secondary metabolites, Marine Pharmacognosy.

Correspondence:
Mr. Sandip Chatterjee
Assistant Professor, Narayan Institute of Pharmacy, Gopal Narayan Singh University, Jamuhar, Sasaram, Rohtas-821305, Bihar, INDIA.
Email: sandipkarna1994@gmail.com
ORCID: 0009-0005-9043-3364.

Received: 26-02-2025;
Revised: 08-04-2025;
Accepted: 06-06-2025.

INTRODUCTION

Marine pharmacognosy, which has its roots in ancient ocean churning myths on study of finding pharmaceuticals in marine organisms. In search of life forms adapted to harsh environments, researchers investigate chemical vents and seabeds. The continued exploration of the ocean's depths not only broadens our knowledge of medicine but also serves as a constant reminder of its limitless potential.[1] Bioprospecting can be defined as the process of conscious and deliberate attempts at seeking bioproducts from biological sources such as plant, microbial and animal origin.[2] These products should therefore be enhanced for the purposes of commercial therapeutic application. It refers to the identification, gathering, as well as extraction of genes from biological specimens of other diversities, which could be used in production of commercialized drugs.[3] This may lead to framing of competitions which in many cases includes the production of toxins, enzymes and other antimicrobial agents including the famous antibiotics.[4] Bioprospecting in the rainbow culture means going out looking for the right samples, the right biological materials. Furthermore, it applies to a range of sophisticated technologies for analysing and furthering those specimens' genetic characteristics convenient for commercial use.[5]

DOI: 10.5530/pres.20252162

The given marine species are commonly 13% of all presently identified living species, which can be between 235,000 and 250,000 in number spread across all kingdom classification groups.[6] This relatively low number may be attributed to two main reasons the first of them is the fact that age differences are not always clear cut, that the meaning of between or within generations is not always quite clear. Second, it may be easier to underestimate oceanic life due to its exploration compared to the terrestrial environment, and moreover, knowledge about deep sea and bacterial or microalgal forms of life is likely more limited than do we know the terrestrial forms of life.[7] Molecular markers and flow cytometry, two recent techniques, paint a far richer and more varied picture of oceanic microorganisms than did traditional taxonomy. Oceanic ecological divisions are less well defined than those of terrestrial ecosystems, which restricts the evolution of new species despite the vastness of the marine environment.[8]

The first extensive named species checklist in marine was delivered by Online database called World Register of marine Species or abbreviated as World Register of marine Species. Presently, World Register of marine Species registers for 243,000 species that are understood and accepted in modern science.[9] Most of increases and decreases in species count can be explained by different factors, such as grouping new domains (Bacteria, Archaea and Viruses), recycling and re-distribution between marine, fresh water and terrestrial surroundings, identification of the synonyms and some updates in many taxonomy groups.[10] Notably, over 1,000 species have been added to each of the groups such as Chlorophyta, rhodophyta, foraminifera, diatoms, euglenozoa (protozoans), some types of crustaceans, small fish or fishes such as amphipods and copepods. Hence, the species accumulation of the total number of 243,000 can be assumed to represent about 98% of all kinds of species described till now. Currently unknown, the hyperdorism of microbes and parasites, deep-sea species and molecular (cryptic) diversity or identification of new species.[9,11]

The resilience of the ocean to environmental changes is bolstered by marine diversity, which guarantees the continuation of essential biophysical processes and productivity. In addition to providing vital products and services that benefit humanity, like carbon sequestration and water purification, diversity helps avert the catastrophic extinction of entire species.[12] The seas provide an awesome mix of goods and services to the society such as; acting as a buffer for the climate, a dumping ground and deposit for wastes and toxins, a source of food and medicine and means of livelihood for many people.[13] Coasts provide designated habitation or living space besides directly and indirectly generating wealth thereby fostering millions of employment opportunities in agriculture-areas.[14] Valuing the products and services of ecosystems helps us understand their potential and our dependence on them. This valuation reveals between welfare gains from using the environment and the loss of benefits from diminished ecosystem services, highlighting the costs of environmental exploitation.[15] Achieving sustainable development requires a connection between biological diversity and marine ecosystems. Their intricate relationships, which involve reinforcement and feedback, highlight how urgently these problems must be resolved in order to protect marine-species.[16] It thus follows that policies and best practices to contain and regulate human impact on the environment and the organismic webs within the context of sustainable carrying capacity management must be put in place and evolved.[17] Marine diversity also includes all the species that are found in the ocean and the interactions between these species and the rest of the environment in relation to genes, species, populations, and ecosystems.[18] Every organization level has structural and functional properties. The evaluation of marine diversity or its aspects can be done at different spatial or temporal perspectives. Thus, the conceptual model of marine biodiversity and their meanings are contingent upon the questions being asked, emphasis on the details, and knowledge of the system and it feedback, primarily.[19] The term 'structural diversity' can therefore be used in the sense of genetic, species, and environmental diversity. For instance, species diversity can be illustrated by the distribution of fish in the North Sea where there are numerous fish species. While genetic diversity relates to the gene's variations in the species, ecosystem and diversity refers to the varieties of communities living in different ecosystems.[20,21]

Marine organisms used for therapeutic purpose

Fish

Fish has long been recognized for its ability to treat a wide range of illnesses. Important amino acids are present in fish proteins in ideal ratios, and including fish in a mixed diet improves the quality of the protein. A thoughtful quantity of these is significant in terms of their potential to improve health. The consumption of oily or fatty fish can reduce the risk of several illnesses, including mental health conditions and vision issues.[22] Fish liver oil is a thick liquid consisting of glycogen and fat. This contains vitamins D and B. There is a lot of iodine in fish body oil. Shark pancreas has a high insulin content, and fish roe is a great source of vitamins B, C, D, and E. Fish oil contains polyunsaturated fatty acids, which have been shown to improve brain function and be very helpful in the treatment of Coronary Heart Disease (CVD).[23]

Seaweed

Seaweed is a well-known source of some very important food hydrocolloids like agar, alginates, and carrageenan. Marine algae, otherwise known as marine macroalgae or seaweeds, are found flourishing in shallow coastal waters and deeper oceanic regions, some species growing at as great a depth as 180 m.[24] Mostly, they have been classified into three main groups: the brown algae, red algae, and green algae. Many biologically and biomedically active substances are present in great abundance in the marine algae, including large amounts of sulfated polysaccharides. They offer a wide range of benefits to health by providing a rich source of dietary fiber, probably the richest sources of omega-3 fatty acids, essential amino acids, and vitamins A, B, C, and E.[25] Edible seaweed has emerged as a novel food with a multitude of bioactive compounds that have the potential to both prevent and treat a wide range of illnesses. In addition to stimulating the thyroid, they may also have antihyperlipidemic, antithrombotic, anti-inflammatory, antiestrogenic, neuroprotective, anticancer, antioxidant, and tissue-healing properties. They might affect immunomodulation as well. These include properties that are antiviral, antifungal, antidiabetic, and anti-hypertensive.[24,26]

Grade categorizing of Seaweed

Now, the current classification has led to grouping algae into four domains: Bacteria, Plantae, Chromistan, and Protozoa. These categories differ morphologically, and in terms of their size.[22,27] Algae can be either phytoplankton or seaweed based on their size and have been classified into two groups. About 5,000 different species have been reported under the category of microalgae, called phytoplankton, while about 6,000 different species have been identified under the category of macroalgae, being seaweed.[28] Primary categories with examples the families are Phaeophyceae, Chlorophyceae, and Rhodophyceae. Based on the colour of the algae in their native environments, marine algae can be classified into three main groups such as brown, red, and green algae. Fucoxanthin, the pigment that gives the Phaeophyceae family its brown hue, serves a variety of physiological and biological purposes, possibly including cancer prevention.[22,29]

Cephalopods

Octopuses

The global diversity of octopus species includes approximately 250 different types.[30,31] The core fishing grounds for these mollusk species lie in the northeastern part of the Pacific Ocean and the Middle Atlantic eastern areas.[32] Panicked The greater part of the catch of octopuses consists of Octopus vulgaris. For example, in Japan, the catch of this species changes within the limits from 60,000 up to 100,000 tons annually. In the Far Eastern seas of Russia, there are 24 species of octopuses.[33] In this way, the continuously rising volume of cephalopod catches can foster environmentally degrading effects within the regions where these sea creatures are processed.[34] This can significantly enhance the yield of marketable products in particular, edible parts with an increased efficiency of waste utilization by utilizing processing's varied components for producing physiologically active substances.[35] Cephalopods are renowned for containing unique biological compounds, often in high concentrations. Lacking an outer shell in most species, they employ various defense mechanisms such as venom to incapacitate prey and predators, and the release of ink to escape from potential threats.[36]

Table 1: Ethnopharmacological approach and biological activity of some marine species.

Marine Species	Method of screening	Dose	Observation	Ethnomedicinal Activity	References
Aspergillus protuberus fungi	Autoantibody screening or Antinuclear antibodies against Human epithelial cell-2.	undetermined	Exhibit potent of uncontrolled growth cell.	Anticancer	[41]
Holothuria atra Sea cucumber	Thioacetamide intoxication in Wister rats.	Mixed extract of sea cucumber 14.4 mg/kg of body weight and thioacetamide 200 mg/kg of body weight.	Active phenolic compound presence of extract show Antioxidant activity.	Reduce oxidative reaction.	[42,43]
Cypraea arabica	Brewer's yeast	20 mL/kg	Both concentration methanolic extract of *Cypraea arabica* show antipyretics activity.	Reduce high fever	[44,45]
Pelvetia siliquosa - marine macroalgae.	Streptozotocin induced in rats.	100 and 300 mg/kg	Glycogen inhibitory.	Potent reduce blood sugar level	[46,47]
Axinella Carteri	Induction Carrageenan in feet.	0.1% of carrageenan applied on paw.	Reduce inflammation on feet.	Anti-inflammatory	[48]

Marine Species	Method of screening	Dose	Observation	Ethnomedicinal Activity	References
Eisenia bicyclis	Omega-3 fatty acid lipid emulsions exhibit anti-inflammatory effects by decreasing Nitric Oxide (NO) production in lipo-stimulated macrophages, achieved through the modulation of inducible nitric oxide synthase protein expression.	Undetermined	Omega-3 fatty acid lipid emulsions demonstrate anti-inflammatory properties, reducing Nitric oxide production in the settings of lipopolysaccharides stimulated macrophages through altered expression of inducible nitric oxide synthetase protein.	Anti-inflammatory	[49,50]
Ecklonia cava	Carrageenan-induced Inflammation in mice.	5 mg/kg to increase 20 mg/kg bodyweight.	Dieckol alleviates carrageenan-induced inflammation by decreasing leukocyte infiltration and the production of pro-inflammatory mediators.	Reduce paw inflammation	[49,51]
Cypraea moneta marine mollusc	Incision of 2 cm wide in hind limb.	3 g powder with 20 mL egg albumin.	Complete tissue regenerate after drug administration.	Wound healing	[52]
Sargassum *ilicifolium*,-brown algae	Separate the gizzard and proventriculus of Gallus gallusdomesticus and place these in aerated Tyrode solution. The test, standard, and control treatments were administered, and then incubated for 8 hr for ulcer formation. Afterwards, the tissues were removed and washed, and examined for ulceration.	400 mg/mL	It has been concluded that the medium dose of the crude sulfated polysaccharide of *Sargassum ilicifolium* showed antiulcer activity compared to standard and control treatments.	Antiulcer	[53,55]
Spatoglossum variabile Brown algae	CCl_4 toxicity induced in Wister rats.	A 20% CCl_4 solution, diluted with dietary cooking oil, was administered at a dosage of 1 mL per 100 g of body weight.	The hepatoprotective activity, however, appears to be due to their radical scavenging potency in regimes that shield cells against free radicals generated in CCl_4-induced hepatotoxicity.	Hepatoprotective	[56]

Marine Species	Method of screening	Dose	Observation	Ethnomedicinal Activity	References
Sigmadocia carnosa marine sponge	Paper disk assay method	500 g/mL) extract	The high activity exhibited by *Sigmadocia carnosa* demonstrated broad-spectrum antimicrobial activity against all microbes tested, except *Fusarium* spp.	Antimicrobial	[57]

Ethnopharmacological approach and biological activities of marine species

While the traditional uses of marine animals and their derived were profoundly diversified, only a few efforts have been made so far to validate the pharmacological benefits related to their functional and medical applications.[37] Accumulating evidence has identified that CSCs confer stem-like phenotypes on cancer cells, which are generally believed to be responsible for recurrence, radio resistance, hormone resistance, chemoresistance, and metastasis.[38] Several studies support the use of these cuttlebone powders for anti-inflammatory and immune-modulating activity and wound healing properties. Moreover, nacre powder has traditionally been used in treating conditions such as palpitations, convulsions, and even epilepsy.[39] Other cytotoxic effects by various holothurians on echinoids eggs include disruption in cell division, cytolysis, and the transformation of the larvae into more animal-like forms. Echinoderms most especially had an immune defense system that was closely like that of mammals.[40] Some marine biological aspects are described in Table 1.

Fount development of marine drugs

The concentrating and multi-targeted elements in the marine medicinal resources, their bio-active chemical core, the action mechanisms of those compounds have been cumbersome in order to the search and development of marine drugs so far, which are, however, required to be analysed thoroughly in a more systematic manner (Figure 1).[58]

Dispute with future trend of marine species

There are tremendous problems associated with the derivation of drugs from marine sources. The differences in environmental conditions may result in different metabolites being produced every time from the same organism.[60] The production of isolated and identified lead compounds on a sustained basis can be a problem. Rather often, the lead compound is available only in small amounts or its isolation becomes technically difficult.[61] With regards to the intended use of a compound, whether it's a drug or a cosmetic the required quantities differ. Whereas preclinical drug development and safety tests may only require a 5 g, clinical trials already run into kilograms, and production of cosmetics many tons.[60] Further research and development of many highly potent novel marine compounds have been frequently hindered by the lack of a secure candidate compound supply chain.[62] Substances isolated from natural sources must be ultimately identified with the substance gained from its biological source to identify a bioactive compound, which is either synthesized or semi-synthesized.[63] Mariculture or marine farming of marine organisms in their own habitat is necessary to grow these organisms.[63,64] Some of the limitations in the development of drugs from marine sources include the use of universal expression systems to biosynthesize small molecules in as high yields as possible, developing genetic tools to explore *in vivo* potential of cultured marine microorganisms, activating silent biosynthetic pathways for the discovery of small molecules through regulatory means.[64] Early efforts in marine natural products chemistry have been focused mainly on metabolite collection from the most easily accessed species.[65] Through technological innovations, scientists are pushing harder for minor metabolites access. This includes the increased use of nuclear magnetic Resourance micro cryogenic and capillary flow probes, exploitation of biological assays in miniaturized volumes like well plate formats, and continued improvements to the techniques used and informatics related to mass spectrometry.[66] Another area of improvement in marine drug discovery programs is related to biological assay methods for extracts, fractions, and pure compounds. Assay-based isolation of marine natural products seems to hold potential for automation and could increase the discovery process for various classes of natural products in nature.[64]

Bioactive compound from Molluscs

Twenty years ago, over 2,600 studies demonstrated the potential benefits of using toxins extracted from marine mollusks for cellular biologists and medical professionals. Out of the approximately 50,000 toxins, only 100 have been studied and identified thus far. This group of Conus species produced small peptides with a structural restriction of 10-30 amino acids, along with other strong nerve toxins. It has been shown that some conotoxins block ion channels that regulate the entry of calcium ions into nerve cells, while other conotoxins bind to n-methyl-D-aspartate receptors to block the passage of potassium or sodium across muscle or nerve cell membranes.[67] In the marine environment, where surfaces are continuously at

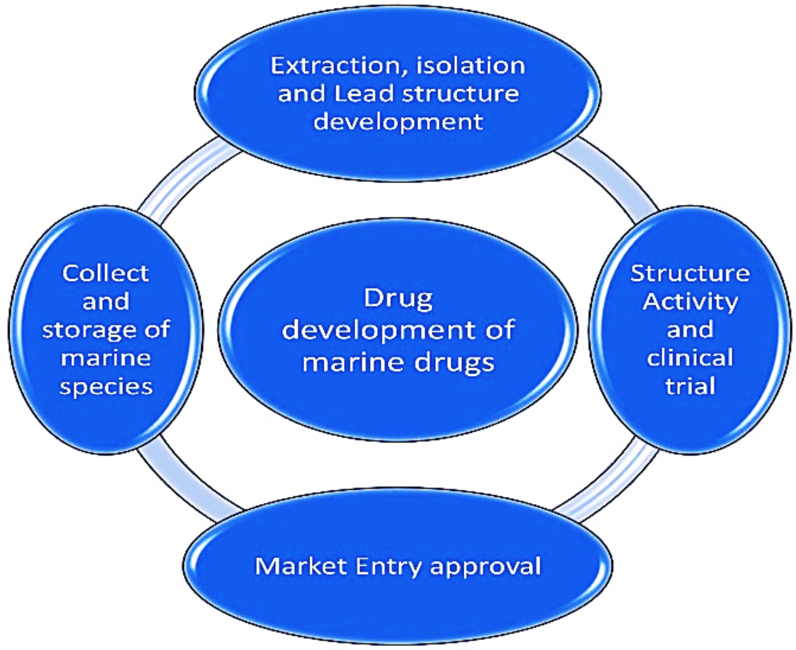

Figure 1: Fount development of marine drugs.[59]

risk of colonization, invertebrates such as bivalve mollusks and cephalopods remain largely free from biofouling. These sedentary organisms appear to manage fouling epibionts through highly effective antimicrobial mechanisms.[68] Such marine invertebrates could be considered an interesting source of potential antimicrobial compounds.[69,70] Nonsteroidal Anti-Inflammatory Drugs (NSAIDs), such as aspirin and ibuprofen, are commonly used to treat inflammatory conditions. However, frequent use of these medications can cause adverse side effects, including the risk of developing stomach ulcers.[71] Thus, investigating the anti-inflammatory and antioxidant properties of bivalve mollusks and developing products from them could significantly reduce the adverse effects of non-steroidal anti-inflammatory drugs.[72] Exploring anti-inflammatory and anti-oxidant properties present in bivalve mollusks and developing products from them could reduce the harm caused by pain killers side effects. It is reported that dried flesh from the New Zealand mussel, *Perna canaliculus*, contains Poly Unsaturated Fatty Acids (PUFAs) with anti-inflammatory activities.[73-75] Neurotoxins and peptides like dolastatin have characterized acetylcholine receptors and shown antineoplastic properties. Other compounds such as ulapualide A and bursatellanin-P exhibit strong cytotoxic, antifungal, and anti-HIV activities. Syntheses of these compounds have clarified their stereochemistry and confirmed their bioactivity. Mollusks continue to be a rich source of diverse metabolites with antibacterial, antioxidant, and anti-inflammatory effects.[76] Metrics on joint pain and inflammatory diseases, a formulation with 100% natural anti-inflammatory ingredients from the green mussel *Perna viridis* has been developed by Central marine fisheries research institute. It revealed that polysaccharides, lysolecithin, and phenolic compounds of *Psychotria viridis* are competitive inhibitors of the inflammatory enzymes Cyclo oxygenase and Lipoxygenases in the inflammation and oxidative stress reactions.[77,78]

Therapeutic efficacy from marine organism

Reduce inflammation (Anti-inflammatory) from marine species

Inflammation is the body's defense against injury and infection. Marine-derived agents like sesquiterpenoids, diterpenes, steroids, and polysaccharides, including chitin and fucoidan, have anti-inflammatory and allergy-regulating properties.[79] Polysaccharides from algae, especially the sulfated ones, demonstrate anti-inflammatory activity both *in vitro* and *in vivo*.[80,82] This is due to their unique structure and relevant physicochemical properties.[83] It is now known to be the carbohydrate-binding sites to which marine lectins owe their anti-inflammatory activity.[84] When given to rats, the lectin produced by the green seaweed *Caulerpa cupressoid* decreases zymosan-induced arthritis, mechanical hyper nociception, and leukocyte accumulation in the temporomandibular joint. While lectin activity is reduced by naloxone or zinc protoporphyrin nine treatments, lectin is still able to inhibit leukocyte influx and suppress the expression of interleukin-1beta and tumour necrosis factor-alpha. These results imply that lectin-mediated suppression of these cytokines contributes to the reduction of inflammation and pain in the joints.[85]

Dispute secondary metabolites show antituberculosis activity

Tuberculosis (TB) is a major health challenge. Marine microorganisms have yielded around 170 new anti-TB compounds. Current drugs, streptomycin and rifampicin, have inhibitory concentrations of 0.2 to 6.0 µg/mL against *Mycobacterium tuberculosis*.[86] Compounds that show a maximum inhibitory value below 64 µg/mL or greater than 75% inhibition at 12.5 µg/mL are potentially anti-tuberculosis compounds. Furthermore, for screening and additional development of these compounds, a selectivity index above 10, based on the half minimal inhibitory concentration, is necessary.[87,88] This means that due to a reason or another, oceans, rich in biodiversity and unique aquatic environments, have been a prolific source of diverse natural products showing considerable antimicrobial, antiviral, antimalarial, antitumor, anti-inflammatory, and antioxidant activities.[89]

Marine organism decreases neurodegenerative Alzheimer's disease

Neurodegenerative diseases like Alzheimer's involve plaques, tangles, synapse loss, and neuronal death. The amyloid cascade theory, which focuses on abnormal amyloid processing, is crucial for understanding the disease. Prevention can be achieved by enhancing the body's natural antioxidant defense and targeting amyloid proteins with antioxidants.[90] A kinase inhibitor found in marine sponges called Hymenialdisine shows promise as a treatment for neurodegenerative conditions like Alzheimer's.[91] Hymenialdisine inhibits several pro-inflammatory cytokines through targeting at the phosphatidylethanolamine signalling pathway and hence could be useful in treating inflammatory diseases.[92]

Marine acquire anticancer activity

Hoiamide A is a neurotoxic lipoprotein mainly isolated from the cyanobacterial extracts of *Symploca* species, a cyanobacterium strain collected from Papua New Guinea, which showed inhibiting ability against the mouse double minutes homolog interaction.[93,94] Niphateolide, a diterpene extracted from the sea sponge of Indonesia, namely *Niphates olemda*, acts as an inhibitor for pifithrin 53-Human homolog of double minute two.[95] Proximicins A, B, and C are furan analogy of netropsin isolated from the marine *Actinomycete verrucosispora*. These compounds are reported to act by upregulation of pifithrin 53 and the cyclin-dependent kinase inhibitor pifithrin 21.[96] Pifithrin 53 Human homolog of double minute two binding inhibitor was isolated from the marine-derived fungus *Arthrinium* species in the hexylitaconic acid form.[97] Lissoclinidine B, a potential compound extracted from *Lissoclinum badium*, has a selective induction for the elimination of cells with altered Pifithrin 53 for cancer treatment.[98] Like anti-mycin from the marine Streptomyces species, N-acetyl-deformylantimycin A (NADA) effectively inhibited Henrietta Lacks cells.[99] Himeic acid A, isolated from the marine fungus *Aspergillus species.* demonstrates inhibitory action against ubiquitin-activating enzyme at 100 mm.[100] In Girolline, isolated from marine sponges *Cymbastela cantharella* and *Axinella brevistyla*, the accumulation of polyubiquitinated Pifithrin 53 promotes growth phase 2 cell cycle arrest in cancer cells.[101] Leucettamol A, isolated from the sea sponge Leucetta aff. microraphis, inhibits the ubiquitin conjugation enzymes of ubiquitin conjugating enzyme 13 and ubiquitin enzyme variant 1A by 50% at a concentration of 50.[102] Dysidiolide is a new alkyl-hydroxybutenolide diterpene from the Bahamian sea sponge, *Dysidea etheria*; it inhibits Complement dependent cytotoxicity 25 protein phosphatase. It delays the cell cycle growth phase 2 transition by dephosphorylating the cyclin B complex at Tyrosine 15.[103] Sulfrcin, a sesquiterpene sulfate from the marine sponge *Ircinia species* inhibits Complement dependent cytotoxicity 25 phosphatase with an half maximal inhibitory concentration of 7.8 mm.[104] It has been shown that coscinosulfate, a sesquiterpene sulfate isolated from the New Caledonian sponge *Coscinoderma mathewsi*, exhibits potent inhibitory activity against Complement dependent cytotoxicity 25A.[105] The Fijian sponge *Xestospongia carbonaria* produces halen quinone, a pentacyclic polyketide molecule and an irreversible inactivator of recombinant human Complement dependent cytotoxicity 25B phosphatase, preventing cell cycle progression into the mitotic phase. The half maximal inhibitory concentration of this compound is 19 mm and is also inhibitory toward the kinase activity of human epidermal growth factor receptor.[106] Secalonic acid D, a mycotoxin isolated from *Penicillium oxalicum*, inhibits deoxyribonucleic acid topoisomerase I and further disrupts the growth first phase of the cell cycle via the β-catenin pathway, leading to significant cytotoxic effects against various human cancer cells. Secalonic acid D slows down the cell cycle progression in human embryonic palatal mesenchymal cells, thereby inhibiting their proliferation. [107,108]

CONCLUSION

Marine species are an abundant source of bioactive compounds with diverse therapeutic properties, including anti-inflammatory, antimicrobial, antioxidant, and anticancer activities, offering significant potential for addressing global health challenges. These compounds, combined with sustainable exploitation of marine biodiversity, present opportunities to discover novel therapeutic agents while preserving ecosystems. Ethnopharmacological knowledge plays a vital role in guiding the identification of these bioactive, bridging traditional medicine and modern pharmacology. Advances in biotechnological tools and high-throughput screening have further accelerated the discovery and development of marine bio actives, facilitating their transition to clinical applications.

However, significant research gaps remain. Despite the vast biodiversity in marine ecosystems, only a small fraction has been systematically explored, with underrepresented regions such as deep-sea and polar ecosystems requiring further attention. Sustainable harvesting practices are not yet standardized, posing challenges to the consistent supply of bioactive compounds. Additionally, the mechanisms of action, bioavailability, and pharmacokinetics of many identified compounds are poorly understood. Translating these discoveries into clinical applications remains a challenge due to regulatory, financial, and technical barriers. The integration of traditional ethnopharmacological knowledge with modern science is still in its infancy, with a need for systematic documentation and validation. Furthermore, the environmental impact of large-scale extraction and cultivation of marine resources is not fully understood, necessitating studies on ecological sustainability. Inconsistent bioprospecting policies also hinder equitable benefit-sharing and access to marine genetic resources. Addressing these gaps will unlock the full therapeutic potential of marine bioactive compounds while ensuring sustainable and ethical utilization of marine biodiversity.

ACKNOWLEDGEMENT

Authors thankful to Narayan Institute of Pharmacy, Jamuhar for cooperation and support.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

TB: Tuberculosis; **DNA:** Deoxyribonucleic Acid; **FDA:** Food and Drug Administration; **HIV:** Human Immunodeficiency Virus; **NSAIDs:** Nonsteroidal Anti-inflammatory Drugs; **PUFAs:** Poly Unsaturated Fatty Acids; **CVD:** Coronary Heart Disease; **CCl4:** Carbon Tetrachloride; N**O:** Nitric Oxide; **U.P.:** Uttar Pradesh; **W.B.:** West Bengal; **A.P.:** Andhra Pradesh; **NADA:** N-acetyl-deformylantimycin A; **CDC25:** Cell Division Cycle 25; **GSK-3β:** Glycogen Synthase Kinase 3 Beta; **HDM2/MDM2:** Human Double Minute 2/Mouse Double Minute 2; **CSCs:** Cancer Stem Cells; **IC_{50}:** Half Maximal Inhibitory Concentration; **mL:** Milliliter; **g:** Gram; **kg:** Kilogram; **mg:** Milligram; **μg:** Microgram; **hr:** Hour; **cm:** Centimeter; **eV:** Electron Volt; **m/z:** Mass-to-charge Ratio; **μm:** Micrometer; **mm:** Millimeter.

AUTHOR CONTRIBUTION

Study design: Ms. Paramita Ganguly, Mr. Sandip Chatterjee, Data Curation: Ms. Puja Saha, Mrs. Prangya Paramita Pati, Supervision: Mr. Sandip Chatterjee, Visualization: Ms. Puja Saha, Ms. Paramita Ganguly, Conceptual: Ms. Paramita Ganguly, Mr. Sandip Chatterjee, Formal analysis: Mrs. Prangya Paramita Pati, Ms. Paramita Ganguly, Writing and drafting: Mr. Sandip Chatterjee, Ms. Puja Saha.

SUMMARY

The bioactive substances that are present in marine environments and have enormous potential for therapeutic uses are covered in this article. These substances have a broad range of pharmacological characteristics, such as antibacterial, anti-inflammatory, antioxidant, and anticancer effects. They are obtained from a variety of species, including algae, sponges, mollusks, and marine microbes. Deeply ingrained in customary methods, ethnopharmacological knowledge acts as a useful manual for determining the therapeutic potential of marine resources, bridging the gap between conventional wisdom and contemporary drug development. These bioactive chemicals have been discovered, isolated, and developed into prospective medicinal medicines more quickly thanks to recent developments in biotechnological technologies and sustainable bioprospecting.

REFERENCES

1. Bali SM, Jain R, Singh MP. A Review on marine pharmacognosy and microbiology with a mythological aspect. Research and review: A journal of pharmacognosy. 2018; 5(1): 25-32. doi: 10.12300/rrjopc.v5i1.83.
2. Sawarkar A, Sharma RK. Gautam V. Pharm Innov J. Bioprospecting: creating value for biodiversity. Vol. 8(4); 2019. p. 256-65.
3. Blaustein R. [560: GRATCO2.0.CO];2. J Bio Sci Genetic resources and the convention on biological diversity. Vol. 56; 2006. p. 560-3. doi: 10.1641/0006-3568(2006)56.
4. Butler MS. Natural product-derived compounds in biodiversity conservation. J Nat Prod. 2008; 74: 496-511. doi: 10.1021/np100550t.
5. Cao S, Kingston DG. Biodiversity conservation and drug discovery can they be combined the Suriname and Madagascar experiences. Pharm Biol. 2009; 47(8): 809-23. doi: 10.1080/13880200902988629, PMID 20161050.
6. Boeuf G. Les specificities de la biodiversite marine. C R Biol. 2011; 334(5-6): 435-40. doi: 10.1016/j.crvi.2011.02.009, PMID 21640952.
7. Bouchet P, Chapter 2, Fundacio´n BBVA. The magnitude of marine biodiversity. In: Duarte CM, editor. The exploration of marine biodiversity: scientific and technological challenges. Bilbao; 2006. p. 33-64.
8. Boeuf G. Marine biodiversity charecteristics. C R Biol. 2011; 334(5-6): 435-40. doi: 10.1016/j.crvi.2011.02.009, PMID 21640952.
9. Costello MJ, Chaudhary C. Marine biodiversity, biogeography, deep-sea gradients, and conservation. Curr Biol. 2017; 27(11): R511-27. doi: 10.1016/j.cub.2017.04.060, PMID 28586689.
10. Costello MJ, Bouchet P, Boxshall G, Fauchald K, Gordon D, Hoeksema BW, *et al.* Global coordination and standardisation in marine biodiversity through the World Register of Marine Species (WoRMS) and related databases. PLOS One. 2013; 8(1): e51629. doi: 10.1371/journal.pone.0051629, PMID 23505408.
11. Appeltans W, Ahyong ST, Anderson G, Angel MV, Artois T, Bailly N, *et al.* The magnitude of global marine species diversity. Curr Biol. 2012; 22(23): 2189-202. doi: 10.1016/j.cub.2012.09.036, PMID 23159596.
12. Marine stewardship council (MSC). Mar Biodivers. 2024.
13. Holmlund CM, Hammer M. Ecosystem services generated by fish populations. Ecol Econ. 1999; 29(2): 253-68. doi: 10.1016/S0921-8009(99)00015-4.
14. Beaumont NJ, Tinch R. Goods and services related to the marine benthic environment. Norwich, UK: centre for social and economic research on the global environment; 2003.
15. De Groot RS, Wilson MA, Boumans RM. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol Econ. 2002; 41(3): 393-408. doi: 10.1016/S0921-8009(02)00089-7.
16. Le H. Importance of marine biodiversity and their implications. J Coast Zone Manag. 2022; 25(7): 1-2. doi: 10.35248/2473-3350.22.25.512.
17. Hatcher BG, Bruce G. Coral reef primary productivity: A hierarchy of pattern and process. Trends Ecol Evol. 1990; 5(5): 149-55. doi: 10.1016/0169-5347(90)90221-X, PMID 21232343.
18. Marubini F, Davies PS. Nitrate increases zooxanthellae population density and reduces skeletogenesis in corals. Mar Biol. 1996; 127(2): 319-28. doi: 10.1007/BF00942117.
19. Le Quéré C, Moriarty R, Andrew RM, Canadell JG, Sitch S, Korsbakken JI, *et al.* Global carbon budget 2015. Earth Syst Sci Data. 2015; 7(2): 349-96. doi: 10.5194/essd-7-349-2015.
20. Mark S, Brumbaugh RD. E. Atlas of Ocean Wealth. Nat Conser. 2016; 7(1): 14.

21. Paulo A, Nunes A. The economics of marine ecosystems: reconciling use and conservation of coastal and marine systems and the underlying natural capital. Environ Resour Econ. 2013; 56(4): 459-65. doi: 10.1007/s10640-013-9732-1.
22. Singh H, Parida A, Debbarma K, Ray DP, Banerjee P. Common marine organisms: a novel source of medicinal compounds. Int J Bioresour Sci. 2020; 7(2): 39-49. doi: 10.3 0954/2347-9655.02.2020.1.
23. Blondeau N. The nutraceutical potential of omega-3 alpha-linolenic acid in reducing the consequences of stroke. Biochimie. 2016; 120: 49-55. doi: 10.1016/j.biochi.2015. 06.005, PMID 26092420.
24. Rajapakse N, Kim SK. Nutritional and digestive health benefits of seaweed. Adv Food Nutr Res. 2011; 64: 17-28. doi: 10.1016/B978-0-12-387669-0.00002-8, PMID 22054935.
25. Alisha DPR, Haider A. Seaweed: nutritional and health benefits. The Pharma. Innov J. 2019; 8(8): 80-3.
26. Khalid S, Abbas M, Saeed F, Bader-Ul-Ain H, Ansar Rasul Suleria H Maiti S, editor. Seaweed Biomaterials. IntechOpen; 2018. doi: 10.5772/intechopen.74060.
27. Zec S. Body weight loss with the aid of alginic acid. Med Arh. 1991; 45(3-4): 113-4. PMID 1366330.
28. Yamamoto I, Maruyama H. Effect of dietary seaweed preparations on 1,2-dimethylhydrazine induced intestinal carcinogenesis in rats. Cancer Lett. 1985; 26(3): 241-51. doi: 10.1016/0304-3835(85)90047-3, PMID 3995498.
29. Vaugelade P, Hoebler C, Bernard F, Guillon F, Lahaye M, Duee PH, *et al.* Non-starch polysaccharides extracted from seaweed can modulate intestinal absorption of glucose and insulin response in the pig. Reprod Nutr Dev. 2000; 40(1): 33-47. doi: 10. 1051/rnd:2000118, PMID 10737549.
30. Besednova NN, Zaporozhets TS, Kovalev NN, Makarenkova ID, Yakovlev YM. Cephalopods: the potential for their use in medicine. Russ J Mar Biol. 2017; 43(2): 101-10. doi: 10.1134/S1063074017020031.
31. Cooke IR, Whitelaw B, Norman M, Caruana N, Strugnell JM. Toxicity in cephalopods. In: Gopalakrishnakone P, Malhotra A, editors. Evolution of venomous animals and their toxins. Dordrecht: Springer Netherlands; 2015. p. 1-15. doi: 10.1007/978-94-007-6727-0_7-1.
32. Silva JGd. The State of World Fisheries and Aquaculture. Rome: food agric. Org., 2014, 3-215.
33. Katugin ON, Shevtsov GA. Cephalopod mollusks of the Russian far eastern seas and adjacent waters of the pacific ocean: the list of species, Izv. Tikhookean Nauchno Issled Inst Rybn Khoz Okeanogr. 2012; 170: 92-8.
34. Koueta N, Viala H, Bihan E. Applications, uses and by-products from cephalopods, cephalopod culture netherlands. Springer-verlag; 2014. p. 131-47. doi: 10.1007/ 978-94-017-8648-5_8.
35. Nair JR, Pillai D, Joseph SM, *et al.* Cephalopod research and bioactive substances. Indian J Geo Mar Sci. 2011; 40(1): 13-27.
36. Cooke IR, Whitelaw B, Norman M, *et al.* Toxicity in cephalopods, in evolution of venomous Animals and their toxins. Dordrecht: Springer-Verlag; 2015. p. 1-15. doi: 10.1007/978-94-007-6458-3_7.
37. Mahomoodally MF, Sanaa DA, Zengin G, Gallo M, Montesano D. Traditional therapeutic uses of marine animal parts and derived products as functional foods-a systematic review. Food Rev Int. 2023; 39(2): 827-57. doi: 10.1080/87559129.2021.1 926486.
38. Domínguez-Martín EM, Tavares J, Ríjo P, Díaz-Lanza AM. Zoopharmacology: a way to discover new cancer treatments. Biomolecules. 2020; 10(6): 817. doi: 10.3390/biom1 0060817, PMID 32466543.
39. González JA, Vallejo JR. The use of shells of marine molluscs in Spanish ethnomedicine: a historical approach and present and future perspectives. Pharmaceuticals (Basel). 2023; 16(10): 1503. doi: 10.3390/ph16101503, PMID 37895974.
40. Verbist JF. Pharmacological effects of compounds from echinoderms. In echinoderm studies. 1993 2020; 4: 111-86.
41. Shukla S, Kim M. Marine natural flora: A potent source of anticancer metabolites. 2016; 45(11): 1412-21.
42. Esmat AY, Said MM, Soliman AA, El-Masry KS, Badiea EA. Bioactive compounds, antioxidant potential, and hepatoprotective activity of sea cucumber (*Holothuria atra*) against thioacetamide intoxication in rats. Nutrition. 2013; 29(1): 258-67. doi: 1 0.1016/j.nut.2012.06.004, PMID 23085016.
43. Feron VJ, de Groot AP, Spanjers MT, Til HP. An evaluation of the criterion organ weight under conditions of growth retardation. Food Cosmet Toxicol. 1973; 11(1): 85-94. doi: 10.1016/0015-6264(73)90064-3, PMID 4716133.
44. Subavathy P, Thilaga RD. Analgesic, antipyretic and anti-inflammatory activities of marine gastropod, *Cypraea arabica* (Linnaeus, 1758). J Exp Zool India. 2018; 21(2): 1033-7.
45. Trelle S, Reichenbach S, Wandel S, Hidebrand P, Tschannen B, Villiger PM, *et al.* Cardiovascular safety of nonsteroidal anti-inflammatory drugs: network meta-analysis. Br Med J. 2011; 342: 70-86. doi: 10.1136/bmj.c7086.
46. Lee YS, Shin KH, Kim BK, Lee S. Anti-diabetic activities of fucosterol from *Pelvetia siliquosa*. Arch Pharm Res. 2004; 27(11): 1120-2. doi: 10.1007/BF02975115, PMID 15595413.
47. Pathak K, Gogoi U, Saikia R, Pathak MP, Das A. Marine-derived antidiabetic compounds: an insight into their sources, chemistry, SAR, and molecular mechanisms. Stud Nat Prod Chem. 2022; 73: 467-504. doi: 10.1016/B978-0-323-91097-2.00004-2.
48. Mayefis D, Idzan NK, Yusri YF. Anti-inflammatory activities of gel extract marine sponges (*Axinella Carteri*) to White mice male. Advances in Health Sciences Research. 2021:(81-90). doi: 10.2991/ahsr.k.211105.012.
49. Khursheed M, Ghelani H, Jan RK, Adrian TE. Anti-inflammatory effects of bioactive compounds from seaweeds, bryozoans, jellyfish, shellfish and peanut worms. Mar Drugs. 2023; 21(10): 524. doi: 10.3390/md21100524, PMID 37888459.
50. Jung HA, Jin SE, Ahn BR, Lee CM, Choi JS. Anti-inflammatory activity of edible brown alga *Eisenia bicyclis* and its constituents fucosterol and phlorotannins in LPS-stimulated RAW264.7 macrophages. Food Chem Toxicol. 2013; 59: 199-206. doi: 10.1016/j.fct.2013.05.061, PMID 23774261.
51. Li Z, Wang Y, Zhao J, Zhang H. Dieckol attenuates the nociception and inflammatory responses in different nociceptive and inflammatory induced mice model. Saudi J Biol Sci. 2021; 28(9): 4891-9. doi: 10.1016/j.sjbs.2021.06.021, PMID 34466063.
52. Immanuel G, Thaddaeus BJ, Usha M, Ramasubburayan R, Prakash S, Palavesam A. Antipyretic, wound healing and antimicrobial activity of processed shell of the marine mollusc *Cypraea moneta*. Asian Pac J Trop Biomed. 2012; 2(3): S1643-6. doi: 1 0.1016/S2221-1691(12)60469-9.
53. Bharathy P, Velmurugan R, AfsiyaBanu A, Prena D, Sakthi S, Monisha P, *et al.* Evaluation of bioactive from marine brown algae *Sargassum ilicifolium* for antiulcer activity using Isolatedchicken Stomachmodel-An alternative approach. J Pharm Neg Results. 2023: 1875-80.
54. Shibata H, Nagaoka M, Takagi IK, Hashimoto S, Aiyama R, Yokokura T. Effect of oligofucose derivatives on acetic acid-induced gastric ulcer in rats. Bio Med Mater Eng. 2001; 11(1): 55-61. PMID 11281579.
55. Raju D, Ilango K, Chitra V, Ashish K. Evaluation of Antiulcer activity of methanolic extract of *Terminaliachebula* fruits in experimental rats. J Pharm Sci Res. 2009; 1(3): 101.
56. Makhmoor T, Naheed S, Shujaat S, Jalil S, Hayat S, Choudhary MI, *et al.* Hepatoprotection by chemical constituents of the marine brown alga *Spatoglossum* variabile: a relation to free radical scavenging potential. Pharm Biol. 2013; 51(3): 383-90. doi: 10.3109/13880209.2012.732582, PMID 23406359.
57. Ely R, Supriya T, Naik CG. Antimicrobial activity of marine organisms collected off the coast of South East India. J Exp Mar Biol Ecol. 2004; 309(1): 121-7. doi: 10.1016/j.jem be.2004.03.010.
58. Chen G, Seukep AJ, Guo M. Recent advances in molecular docking for the research and discovery of potential marine drugs. Mar Drugs. 2020; 18(11): 545. doi: 10.3390/ md18110545, PMID 33143025.
59. Sruthi V, Sharone Grace NS, Monica N, Manoj Kumar VM. Marine pharmacology: an ocean to explore novel drugs. Int J Basic Clin Pharmacol. 2020; 9(5): 822-8. doi: 10.18 203/2319-2003.ijbcp20201767.
60. Martins A, Vieira H, Gaspar H, Santos S. Marketed marine natural products in the pharmaceutical and cosmeceutical industries: tips for success. Mar Drugs. 2014; 12(2): 1066-101. doi: 10.3390/md12021066, PMID 24549205.
61. Molinski TF, Dalisay DS, Lievens SL, Saludes JP. Drug development from marine natural products. Nat Rev Drug Discov. 2009; 8(1): 69-85. doi: 10.1038/nrd2487, PMID 19096380.
62. Radjasa OK, Vaske YM, Navarro G, Vervoort HC, Tenney K, Linington RG, *et al.* Highlights of marine invertebrate-derived biosynthetic products: their biomedical potential and possible production by microbial associants. Bioorg Med Chem. 2011; 19(22): 6658-74. doi: 10.1016/j.bmc.2011.07.017, PMID 21835627.
63. Maier ME. Structural revisions of natural products by total synthesis. Nat Prod Rep. 2009; 26(9): 1105-24. doi: 10.1039/B809658A, PMID 19693411.
64. Gerwick WH, Moore BS. Lessons from the past and charting the future of marine natural products drug discovery and chemical biology. Chem Biol. 2012; 19(1): 85-98. doi: 10.1016/j.chembiol.2011.12.014, PMID 22284357.
65. Iyer U, Kadambi VJ. Antibody drug conjugates - Trojan horses in the war on cancer. J Pharmacol Toxicol Methods. 2011; 64(3): 207-12. doi: 10.1016/j.vascn.2011.07.005 , PMID 21843648.
66. Gerwick WH, Fenner AM. Drug discovery from marine microbes. Microb Ecol. 2013; 65(4): 800-6. doi: 10.1007/s00248-012-0169-9, PMID 23274881.
67. Chandran B, Rameshkumar G, Ravichandran S. Antimicrobial activity from the gill extraction of *Perna viridis*. Glob J Biotechnol Biochem. 2009; 4: 88-92.
68. Tincu JA, Taylor SW. Antimicrobial peptides from marine invertebrates. Antimicrob Agents Chemother. 2004; 48(10): 3645-54. doi: 10.1128/AAC.48.10.3645-3654.2004 , PMID 15388415.
69. Bansemir A, Blume M, Schröder S, Lindequist U. Screening of cultivated seaweeds. Antimicrob Agents Chemother. 2006; 48: 3645-54. doi: 10.1016/j.aquaculture.2005 .11.051.
70. Mayer AM, Rodríguez AD, Berlinck RG, Hamann MT. Marine pharmacology in 2003-4: marine compounds with anthelmintic antibacterial, anticoagulant, antifungal, anti-inflammatory, antimalarial, antiplatelet, antiprotozoal, antituberculosis, and antiviral activities; affecting the cardiovascular, immune and nervous systems, and other miscellaneous mechanisms of action. Comp Biochem Physiol C Toxicol Pharmacol. 2007; 145(4): 553-81. doi: 10.1016/j.cbpc.2007.01.015, PMID 17392033.
71. Couch RA, Ormrod DJ, Miller TE, Watkins WB. Anti-inflammatory activity in fractionated extracts of the green-lipped mussel. N Z Med J. 1982; 95(720): 803-6. PMID 6961318.

72. Miller TE, Dodd J, Ormrod DJ, Geddes R. Anti-inflammatory activity of glycogen extracted from Perna canaliculus (NZ green-lipped mussel). Agents Actions. 1993; 38 Spec No:C139-42. doi: 10.1007/BF01991164, PMID 8317309.
73. Croft JE. Relief from arthritis: a safe and effective treatment from the ocean. Wellingborough, UK: Thorsons Publishers; 1979. p. 128.
74. Zwar D. The magic mussel – arthritis another way? 2nd ed. Cairns, Australia: Ideas Unlimited; 1994. p. 108.
75. Gibson RG, Gibson SL. Seatone in arthritis. Br Med J (Clin Res Ed). 1981; 283(6304): 1472. doi: 10.1136/bmj.283.6304.1472-a, PMID 6797585.
76. Chakraborty K, Vijayan KK, Vijayagopal P. Bioactive compounds and nutraceuticals from marine organisms. Vistas Mar Biotechnol. 2010: 272-9.
77. Chakraborty K, Vijayagopal P, Asokan PK, Vijayan KK. Green mussel (*Perna viridis* L.) as healthy food, and as a nutraceutical supplement. Mar Biotechnol Div. 2010: 89-94.
78. Vo TS, Ngo DH, Kang KH, Jung WK, Kim SK. The benefcial properties of marine polysaccharides in alleviation of allergic responses. Mol Nutr Food Res. 2015; 59(1): 129-38. doi: 10.1002/mnfr.201400412, PMID 25379652.
79. Cardoso ML, Xavier CA, Bezerra MB, Paiva AO, Carvalho MF, Benevides NM, *et al.* Assessment of zymosan-induced leukocyte infux in a rat model using sulfated polysaccharides. Planta Med. 2010; 76(2): 113-9. doi: 10.1055/s-0029-1186003, PMID 19653146.
80. Matsui MS, Muizzuddin N, Arad S, Marenus K. Sulfated polysaccharides from red microalgae have antiinfammatory properties *in vitro* and *in vivo*. Appl Biochem Biotechnol. 2003; 104(1): 13-22. doi: 10.1385/abab:104: 1:13, PMID 12495202.
81. Medeiros VP, Queiroz KC, Cardoso ML, Monteiro GR, Oliveira FW, Chavante SF, *et al.* Sulfated galactofucan from Lobophora variegata: anticoagulant and anti-infammatory properties. Biochemistry (Mosc). 2008; 73(9): 1018-24. doi: 10.1134 /s0006297908090095, PMID 18976219.
82. De Jesus Raposo MF, De Morais AM, De Morais RM. Marine polysaccharides from algae with potential biomedical applications. Mar Drugs. 2015; 13(5): 2967-3028. doi: 10.3390/md13052967, PMID 25988519.Doi-10.3390/md13052967.
83. Cheung RC, Wong JH, Pan W, Chan YS, Yin C, Dan X, *et al.* Marine lectins and their medicinal applications. Appl Microbiol Biotechnol. 2015; 99(9): 3755-73. doi: 10.1007 /s00253-015-6518-0, PMID 25794876.
84. da Conceição Rivanor RL, Chaves HV, Do Val DR, De Freitas AR, Lemos JC, Rodrigues JA, *et al.* A lectin from the green seaweed Caulerpa cupressoides reduces mechanical hyper-nociception and infammation in the rat temporomandibular joint during zymosan-induced arthritis. Int Immunopharmacol. 2014; 21(1): 34-43. doi: 10.1016/j. intimp.2014.04.009, PMID 24768528.
85. Barry CE III, Slayden RA, Sampson AE, Lee RE. Use of genomics and combinatorial chemistry in the development of new antimycobacterial drugs. Biochem Pharmacol. 2000; 59(3): 221-31. doi: 10.1016/s0006-2952(99)00253-1, PMID 10609550.
86. Copp BR. Antimycobacterial natural products. Nat Prod Rep. 2003; 20(6): 535-57. doi: 10.1039/b212154a, PMID 14700198.
87. Tiberi S, Muñoz-Torrico M, Duarte R, Dalcolmo M, D'Ambrosio L, Migliori GB. New drugs and perspectives for new anti-tuberculosis regimens. Pulmonology. 2018; 24(2): 86-98. doi: 10.1016/j.rppnen.2017.10.009, PMID 29487031.
88. Patridge E, Gareiss P, Kinch MS, Hoyer D. An analysis of FDA approved drugs: natural products and their derivatives. Drug Discov Today. 2016; 21(2): 204-7. doi: 10.1016/j. drudis.2015.01.009, PMID 25617672.
89. Karran E, Mercken M, De Strooper B. The amyloid cascade hypothesis for Alzheimer's disease: an appraisal for the development of therapeutics. Nat Rev Drug Discov. 2011; 10(9): 698-712. doi: 10.1038/nrd3505, PMID 21852788.
90. Meijer L, Thunnissen AM, White AW, Garnier M, Nikolic M, Tsai LH, *et al.* Inhibition of cyclin-dependent kinases, GSK-3β and CK1 by hymenialdisine, a marine sponge constituent. Chem Biol. 2000; 7(1): 51-63. doi: 10.1016/s1074-5521(00)00063-6, PMID 10662688.
91. Sharma V, Lansdell TA, Jin G, Tepe JJ. Inhibition of cytokine production by hymenialdisine derivatives. J Med Chem. 2004; 47(14): 3700-3. doi: 10.1021/jm040 013d, PMID 15214798.
92. Malloy KL, Choi H, Fiorilla C, Valeriote FA, Matainaho T, Gerwick WH. A marine cyanobacteria-derived inhibitor of p53/ MDM2 interaction. Bioorg Med Chem Lett. 2012; 22(1): 683-8. doi: 10.1016/j.bmcl.2011.10.054, PMID 22104152.
93. Mi Y, Zhang J, He S, Yan X. New peptides isolated from marine cyanobacteria, an overview over the past decade. Mar Drugs. 2017; 15(5): 132. doi: 10.3390/md1505 0132, PMID 28475149.
94. Kato H, Nehira T, Matsuo K, Kawabata T, Kobashigawa Y, Morioka H, *et al.* Niphateolide A: isolation from the marine sponge *Niphates olemda* and determination of its absolute confguration by an ECD analysis. Tetrahedron. 2015; 71(38): 6956-60. doi: 10.1016/j.tet.2015.07.009.
95. Schneider K, Keller S, Wolter FE, Röglin L, Beil W, Seitz O, *et al*. Proximicins A, B, and C-antitumor furan analogues of netropsin from the marine actinomycete Verrucosispora induce upregulation of p53 and the cyclin kinase inhibitor p21. Angew Chem Int Ed Engl. 2008; 47(17): 3258-61. doi: 10.1002/anie.200705295, PMID 18348121.
96. Tsukamoto S, Yoshida T, Hosono H, Ohta T, Yokosawa H. Hexylitaconic acid: a new inhibitor of p53-HDM2 interaction isolated from a marine-derived fungus, *Arthrinium* sp. Bioorg Med Chem Lett. 2006; 16(1): 69-71. doi: 10.1016/j.bmcl.2005.09.052, PMID 16246554.
97. Clement JA, Kitagaki J, Yang Y, Saucedo CJ, O'Keefe BR, Weissman AM, *et al.* Discovery of new pyridoacridine alkaloids from *Lissoclinum* cf. badium that inhibit the ubiquitin ligase activity of Hdm2 and stabilize p53. Bioorg Med Chem. 2008; 16(23): 10022-8. doi: 10.1016/j.bmc.2008.10.024, PMID 18977148.
98. Zhang W, Che Q, Tan H, Qi X, Li J, Li D, et al. *Marine Streptomyces* sp. derived antimycin analogues suppress HeLa cells via depletion HPV E6/E7 mediated by ROS-dependent ubiquitin-proteasome system. Sci Rep. 2017; 7: 42180. doi: 10.1038/srep42180, PMID 28176847.
99. Tsukamoto S, Hirota H, Imachi M, Fujimuro M, Onuki H, Ohta T, *et al.* Himeic acid A: a new ubiquitin-activating enzyme inhibitor isolated from a marine-derived fungus, *Aspergillus* sp. Bioorg Med Chem Lett. 2005; 15(1): 191-4. doi: 10.1016/j.bmcl.2004.1 0.012, PMID 15582438.
100. Tsukamoto S, Yamashita K, Tane K, Kizu R, Ohta T, Matsunaga S, *et al.*, Bulletin P. Girolline, an antitumor compound isolated from a sponge, induces G2/M cell cycle arrest and accumulation of polyubiquitinated p53. Biol Pharm Bull. 2004; 27(5): 699-701. doi: 10.1248/bpb.27.699, PMID 15133248.
101. Tsukamoto S, Takeuchi T, Rotinsulu H, Mangindaan RE, Van Soest RW, Ukai K, *et al.* Leucettamol A: a new inhibitor of Ubc13-Uev1A interaction isolated from a marine sponge, *Leucetta* aff. microrhaphis. Bioorg Med Chem Lett. 2008; 18(24): 6319-20. doi: 10.1016/j.bmcl.2008.10.110, PMID 19006668.
102. Gunasekera SP, McCarthy PJ, Kelly-Borges M, Lobkovsky E, Clardy J. Dysidiolide: a novel protein phosphatase inhibitor from the Caribbean sponge Dysidea Etheria de Laubenfels. J Am Chem Soc. 1996; 118: 8759-60. doi: 10.1021/ja961961+.
103. Nagle DG, Zhou YD, Mora FD, Mohammed KA, Kim YP. Mechanism targeted discovery of antitumor marine natural products. Curr Med Chem. 2004; 11(13): 1725-56. doi: 10. 2174/0929867043364991, PMID 15279579.
104. Loukaci A, Le Saout I, Samadi M, Leclerc S, Damiens E, Meijer L, *et al.* Coscinosulfate, a CDC25 phosphatase inhibitor from the sponge Coscinoderma mathewsi. Bioorg Med Chem. 2001; 9(11): 3049-54. doi: 10.1016/S0968-0896(01)00208-5, PMID 11597488.
105. Skropeta D, Pastro N, Zivanovic A. Kinase inhibitors from marine sponges. Mar Drugs. 2011; 9(10): 2131-54. doi: 10.3390/md9102131, PMID 22073013. Skropeta D, Pastro N, Zivanovic A. Kinase inhibitors from marine sponges. Mar Drugs. 2011; 9(10): 2131-54. doi: 10.3390/md9102131, PMID 22073013. Skropeta D, Pastro N, Zivanovic A. Kinase inhibitors from marine sponges. Mar Drugs. 2011; 9(10): 2131-54. doi: 10.3390/md9102131, PMID 22073013.
106. Cherigo L, Lopez D, Martinez-Luis S. Marine natural products as breast cancer resistance protein inhibitors. Mar Drugs. 2015; 13(4): 2010-29. doi: 10.3390/md130 42010, PMID 25854646.
107. Zhang JY, Tao LY, Liang YJ, Yan YY, Dai CL, Xia XK, *et al.* Secalonic acid D induced leukemia cell apoptosis and cell cycle arrest of G1 with involvement of GSK-3β/β-catenin/c-Myc pathway. Cell Cycle. 2009; 8(15): 2444-50. doi: 10.4161/cc. 8.15.9170, PMID 19571678.

Cite this article: Ganguly P, Saha P, Chatterjee S, Pati PP. Natural Marine Species Bioactive Compounds and their Ethnopharmacological Approach from Ecological Biodiversity: Sustainable Therapeutic Properties. Pharmacog Res. 2025;17(3):697-706.