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Biopiracy of marine organisms: an emerging paradigm

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Abstract

The modern drugs commercially available nowadays are widely isolated from natural reservoirs. Penicillin was isolated from a mold and Aspirin was isolated from a willow tree. The recent advanced scientific research has further extended the explorations for medicinal drugs in the marine reservoirs. Some of the drugs based on marine organisms have proved to be quite effective in treating diseases like cancer and Human Immunodeficiency Virus. The different marine organisms like sponges, molluscs, echinoderms, tunicates and bryozoans are being actively used or trialled for the preparation of useful pharmaceutical drugs. The scientists, researchers and pharmaceutical corporations of the world compete to discover new drugs from global marine reservoirs. The marine organisms are freely available in the marine ecosystems and lack of global legislations provide free hands to the biopirates to exploit the marine reservoirs and isolate different organisms from it. The enormous explorations in the marine reservoirs by the biopirates are causing damage to its ecosystems and its lifeforms. In this investigation, it was concluded that though scientific explorations should be allowed in the marine reservoirs for producing lifesaving drugs but overexploitation of marine reservoirs should be prohibited. It is suggested through this investigation that proper tracking of marine reservoirs is the present requirement to face the challenges being laid down by the biopirates.

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Introduction

The marine water accounts for about 97% of total water present on the land area of this blue planet (Munn, 2003). The marine ecosystems comprise of rich biological diversity that includes, plants, animals, and various microscopic life forms. The scientific explorations around the globe are incorporating global marine ecological resources. The fact sheet of United Nations interprets in the ocean conference held in the year 2017 that the global oceans comprises of 500000 and 10 million marine species (United Nations, 2017). The marine phytoplanktons produces 50 percent of oxygen on earth (Bittel, 2019). The species heterogeneity associated with the marine ecosystems lies between 0.7 to 1.0 million species with millions of bacteria, viruses and other microbial species (United Nations, 2017). The results of various research investigations depict that global marine resources have been often utilized by local individuals residing near the marine reservoirs as nutritional source and for curing health ailments. At present, about 7.5% of the global marine reservoirs are safeguarded (Briggs, 2020). World Wildlife Federation suggests a term 'Marine Protected Areas' that involves efficiently managing or safeguarding the marine ecological reserves and the habitats of various life forms associated with it (Reuchlin-Hugenholtz and McKenzie, 2015). According to the International Union for Conservation of Natural Resources during world conservation congress, various global states agreed Motion 53 that mainly urged to safeguard 30% of the global marine ecosystems up to 2030 (Dinmore, 2016).

Various historical evidences depict that variety of marine life forms were employed for medicinal usage. The written record of medicinal herbs dates back to about 5000 years (Pan *et al.,* 2014). In China in 2953 BCE in the empire of Fu Hsi taxes were levied on the medicines derived from fish (Newman, 2019). Hippocrates in 400 BCE observed antibiotic efficacy of some sponges and used it for curing wounds of soldiers (Munn, 2003). The personal physician of the emperor Claudius suggested the usage of electric fish viz. *Torpedo nobilana* secretions to treat headaches and even migraines (Janik, 2014). Romans used the algae as medicines for the treatment of various health ailments (Anis *et al.,* 2017). Khalilieh and Boulos in their investigation described notable uses of micro and macro algae extracts for curing health disorders (Khalilieh and Boulos, 2006). Secundus in 1603exhibited the application of stingray spines to treat toothaches (Narchi, 2015). The ancient Chinese medicinal literature available in Chinese Materia Medica depicts that various marine organisms were utilized in the ancient Chinese traditional medicinal therapies (Fu *et al.,*2016). The use of marine invertebrates for healing purposes has also been reported during ancient Greek times and the initial Byzantium (Voultsiadou, 2010). The use of marine turtles for preparation of traditional medicines has also been reported (Alves, 2006). The treatment of human health disorders from animals and their isolated compounds is often called as zootherapy (Alves, 2006). In different regions of Brazil, the fisherman uses different species of fish for medicinal purposes (Pinto *et al.,* 2015). A well-known medical Scholar Ibn Sina also popularly known as Avicenna in his book "Canon of Medicine" depicts isolation of medicinal material from skin of marine animals (Nizamoglu, 2015). There are various marine organisms like sponges, corals, crabs, mollusks, and sea horses that are used in various parts of Asia and other global regions in traditional medicines (Kataona, 2015). Additionally, the sea life natural stores are also the supplies of antimicrobial constituents like the cationic antimicrobial peptides (Patrzykat, 2003).

From the above historical evidences, it is clear that the marine organisms have been employed for therapeutic purposes since ages. These evidences act as an attraction for the pharmaceutical corporations, researchers and scientists to deeply explore marine ecosystems for new biological innovations. With the passage of time and advancement in the technical research, the explorations in the ocean reservoirs have enormously risen. The insufficiency of global legislations to restrict uncontrolled explorations of global marine reserves is seriously causing damage to the global ocean life forms. The biopirates are exponentially isolating the marine organisms for

manufacturing therapeutic drugs and subjecting them to patenting. The patent war between the pharmaceutical corporations to conquer monopoly over the marine ecosystems is definitely a matter of fact in the current scenario. Various pharmaceutical corporations are involved in manufacturing potential therapeutic compounds from marine lifeforms. Some of the significant pharmaceutical corporations are Santen Pharmaceutical Co. Ltd., Icos corporation, Island Kinetics Inc., HRD corporations, Procter & Gamble Company, Heliae Development LLC. and Codexis Inc. (Ninawe and Indulkar, 2014). The various patents being issued with respect to biologically active compounds isolated from marine organisms include US8486960 B2, US8450489 B2, US8445701 B2, US8586597 B2, USRE44599 E1, US8293943 B1, US8524980 B2, and US8586051 B2. (Ninawe and Indulkar, 2014). The pharmaceutical corporations are just performing theft of nature as biopirates and generating huge financial assets. The present study basically aims to explore this new challenge that is being created by the biopirates concerning biopiracy of global marine lifeforms.

Material and methods

Material

The material used for this study was the secondary data that was collected from the secondary sources. The secondary sources included published research articles in journals, books, magazines and conferences. It also included news, reports and data from different websites.

Methods

The present investigation adopts an exploratory research methodology. The collected secondary data was subjected to analysis of observations. The observations were taken for evaluations and further to draw a conclusion.

Results and discussion

Results

Principle behind the exploration of drugs in marine organisms

Even after the long adaption cycle followed during the advancement of life, some prominent traits of marine creatures are similar to that of man. These structural similarities suggests that different species in the present world have common descendants and this further authenticate the mechanism of evolution. The recent scientific researches suggests utilizing those marine organisms which are intimately correlated to humans and that can be applied as biomedical models for studies concerning various human health disorders. The gills present in marine green shore crabs acts as a useful biomedical model to understand transportation of sodium in mammalian kidneys (National Research Council, 1999). The vestibular systems of toadfish bear similarity with the vestibular system of humans (National Research Council, 1999). The eyes of *Squalus acanthias* which is a spiny dog shark fish that is used to understand the eye disorders in humans (National Research Council, 1999). The sea slugs have remarkable similar genes in its brain like those found in humans (Choi, 2006). Such genetic similarity is being utilized for treating diseases like Parkinson's and Alzheimer's in humans. The genomic sequence of Sea Urchin have shown close relation to human beings (NSF, 2006). The eyes of octopus are very similar to like that of human eyes (Ogura *et al.,* 2004). These structural similarities between human and marine lifeforms suggests that though several physiological changes have occurred during the adoption of origin of life still various structural features of living organisms remained unchanged. The structural similarities between humans and certain marine organisms attracts scientists and researchers around the world to exploit them for deriving novel pharmaceutical bioactive compounds for manufacturing effective drugs.

Significant bioactive molecules isolated from marine organisms

Most of the drugs used in modern days are derived from nature. Aspirin was derived from a willow tree (Desborough and Keeling, 2017). Penicillin antibiotic was discovered from a mold (Ikenson, 2012). The demand for new drugs is rising in the global scenario that has increased the demand for novel drug discoveries from nature. This has further encouraged exhaustive explorations in nature including marine reservoirs.

Some of the significant biochemicals derived from marine lifeforms and that are being used for curing different health disorders are given as under:

Ecteinascidin743

It is isolated from *Ecteinascidia turbinata* (Fig. 1). It has been trialled on humans for treating, ovarian and solid tumours (National Research Council, 1999).

Fig. 1. *Ecteinascidia turbinate.*
Image source: https://naturalhistory.si.edu

Discodermalide

It is derived from deep marine sponges of genus *Discodermia* (Fig. 2) that possess traits of anticancer agent and immunosuppressant (National Research Council, 1999).

Fig. 2. *Discodermia dissolute.*
Image source: https://www.researchgate.net

Bryostatin

It is isolated from bryozoan, *Bugula neritina* (Fig. 3) that possess the potential of curing melanoma and leukaemia (National Research Council, 1999).

Fig. 3. *Bugula neritina.*
Image source: http://nathistoc.bio.uci.edu

Pseudopterosins

It is derived through an octocoral marine whip called, *Pseudopterogorgia elisabethae* (Fig. 4), which exhibits analgesic and anti-inflammatory properties. It can be used for reducing swelling, dermal irritations and for stimulating healing of wounds (National Research Council, 1999).

Fig. 4. *Pseudopterogorgia elisabethae.*
Image Source: https://www.coralandfishstore.nl

w-Conotoxin MVIIA

This biochemical is derived through an ocean cone snail called as *Conus magnus* (Fig. 5). It acts as a potent pain killer (Safavi-Hemami *et al.,* 2019).

Fig. 5. *Conus magnus.*
Image Source: http://www.marinespecies.org

Drugs derived from marine organisms and approved as medicines

Different medications created from marine living beings are under clinical preliminaries and some of which are even endorsed as meds, as discussed beneath (Mayer *et al.,* 2010):

Cytarabine

It is a nucleoside derived from a marine sponge often known as *Tethya crypta* and found in the Caribbean region. The compound name of this drug is Ara-C and its trademark is Cytosar-U®. The corporations manufacturing this drug are Bedford laboratories and Enzon pharmaceuticals. It has been approved by the Food and Drug Administration in the United States for treating different types of leukaemias.

Vidarabine

It is also derived from *T. cryta*. The compound name of this drug is Ara-A and its tradename is Vira-A®. The corporation manufacturing this drug is King Pharmaceuticals. It is also approved by the Food and Drug Administration in the United States for treatment of type 1 and type 2 epithelial keratitis, superficial keratitis and acute keratoconjunctivitis.

Ziconotide

It is extracted from a marine snail, *Conus magnus*. Its trading name is Prialt®. The corporation manufacturing this drug is Elan. It is a potent analgesic that is approved by the Food and Drug Administration in America.

Trabectedin

This medication is derived from marine tunicate species *Ecteinascidia turbinata* observed in the Caribbean and Mediterranean oceans. The compound name of this drug is ET-743. The tradename of this medication is Yondelis®. The company manufacturing this medication is Pharmamar.

It's not only been endorsed by the European Union but also been proved to be a compelling drug in treating sarcoma of delicate tissues and ovarian malignancy.

Discussion

Evidences on biopiracy of medicines derived from marine organisms

In this modern era through the cutting edge logical procedures and studies, tremendous bioactive ingredients have been obtained from the ocean life forms. These bioactive agents have been utilized for creating drugs that are productive in treating dangerous infections in people. Certain marine creature that has been biopirated for creating therapeutic medications against various sicknesses is portrayed as under:

Marine Snail biopiracy

Conus magnus is a marine poisonous snail that uses its toxin to catch fishes for feed (Olivera *et al.,* 2013). The toxin produced by this marine snail is called conotoxin, that is used for various pharmaceutical medicinal preparations and is marketed as Prialt (Olivera *et al.,* 2013). Similar to conotoxin alternative drug is being produced viz. Ziconotide and it is being suggested for the treatment of cancers, Human Immunodeficiency Virus, nervous disorder and as a pain killer (Olivera *et al.,* 2013).

Marine Sponges biopiracy

Recent studies suggest that about 5300 different biomolecules have been derived and identified from sponges collected from different marine reservoirs (Anjum *et al.,* 2016). The marine sponges possess bioactive molecules that have shown efficacy in curing infections in humans, developed due to bacteria, viruses, fungi and protozoa (Indraningrat *et al.,* 2016). Ocean sponges have also been recommended in treating tumours and heart disorders (Anjum *et al.,* 2016). *Halichondria okadai* is an ocean sponge that is being used by researchers for isolation of a biochemical to produce a replicated biomolecule viz. eribulin that is effective in treating breast cancer in women (Shetty and Gupta, 2014).

Another species of an ocean sponge *Jaspis* shows efficacy to restrict *Candida albicans* in a mouse model (Donia and Hamann, 2003). The decoction derived from an ocean sponge *Spongia officinalis* depicts anti-inflammatory activity that is being

investigated through *in vivo* study in the rat model (Dellai *et al.,* 2012). *Sarcotragus sp*. also called as Tunisian marine sponge exhibits positive actions against Leishmania infection (Kahla-Nakbi *et al.,* 2010). A marine sponge found in Indonesia in Manado Bay region secretes a chemical known as Manzamide A, that is effective against cervical cancer (Rees, 2020). Likewise, a Japanese marine sponge called *Acanthella sp*. has been used for isolating an active compound known as Isonitrile, which possesses antimalarial properties (Malve, 2016).

Marine Bacteria biopiracy

A bacterial species called as *Serinicoccus* is a marine bacteria that is utilized by scientist to isolate a biological compound known as Seriniquinone and it has proved to be successful in destroying cancer cells in the laboratory (Trzoss *et al.,* 2014).

Marine Squirt biopiracy

Ecteinascidia turbinata is a marine invertebrate that is being used in deriving a medicinal compound trabectedin (National Center for Biotechnology Information, 2021). This compound is found to be effective in clinical trials against different types of cancers that include breast and prostate (National Center for Biotechnology Information, 2021).

Marine Seaweed biopiracy

Laminaria ochroleuca (Fig. 6) is a marine seaweed that has been investigated for developing a bioactive compound used against *Staphylococcus aureus* and *Candida albicans* (GEN, 2019).

Fig. 6. *Laminaria ochroleuca*.
Image Source: https://www.marlin.ac.uk

Marine horseshoe crab biopiracy

Recently it was reported that the Horseshoe crab (Fig. 7) blood might be very effective in developing Covid-19 vaccine (Arnold, 2020). The blue blood of horseshoe crab is very valuable and in demand by the research communities around the world (Arnold, 2020). He further worries that this can further encourage deterioration of the marine ecosystems.

Fig. 7. Horseshoe crab.
Image Source: https://www.nwf.org

Marine diatoms biopiracy

Phacodactylum tricornutum (Fig. 8) is a marine diatom that is being utilized to drive a fatty acid called Eicosapentaenoic acid (Pudney *et al.,* 2019). This acid exhibits antibacterial activity against various gram-negative and positive bacteria and also against a multidrug-resistant variety of bacteria i.e. *Staphylococcus aureus* (Debois *et al*., 2009).

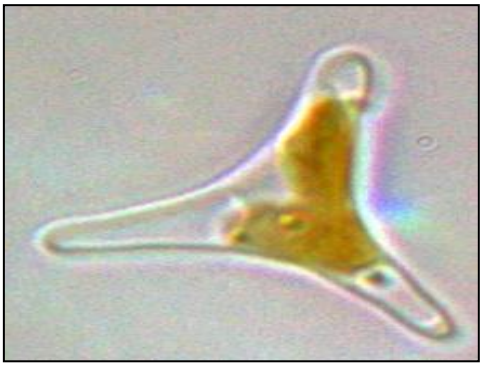

Fig. 8. *Phacodactylum tricornutum*.
Image Source: https://mycocosm.jgi.doe.gov

Marine fungus biopiracy

Cephalosporium acremonium (Fig. 9) is a marine fungus from which a bioactive compound known as

Cephalosporin C is derived that exhibits antimicrobial activity (Silber *et al.,* 2016).

Fig. 9. *Cephalosporium acremonium*.
Image Source: https://moldhelpforyou.com

Marine seaweed biopiracy

Ulva reticulata is a south Indian green seaweed that possesses bioactive molecules showing neuroprotection properties (Suganthy *et al*., 2010). The compounds of this seaweed are now being tested for treating Alzheimer's disease (Suganthy *et al*., 2010).

Marine tunicate biopiracy

Ecteinascidia turbinata possess bioactive molecule called as Ecteinascidin that has been proved to be effective in treating cancer (Palanisamy *et al.,* 2017).

Marine bryozoans biopiracy

Bugula neritina is a Bryozoan that contains a chemical called as Bryostatin that has been under clinical trials to treat cancer and Alzheimer's disease (Pinto *et al.,* 2015).

Marine sea whip biopiracy

A Sea whip known as *Pseudopterogorgia elisabethae* contains a bioactive compound called Pseudopterosins, that has proved to be a good analgesic and antiinflammatory agent (Mans, 2016).

Marine squid biopiracy

The scientists at the Marine Biological Laboratory located in Massachusetts have identified a squid species, *Doryteuthis pealeii* (Fig. 10) that can edit its genetic code (Greenfieldboyce, 2020). This discovery is being explored to develop gene-edited drugs and vaccines.

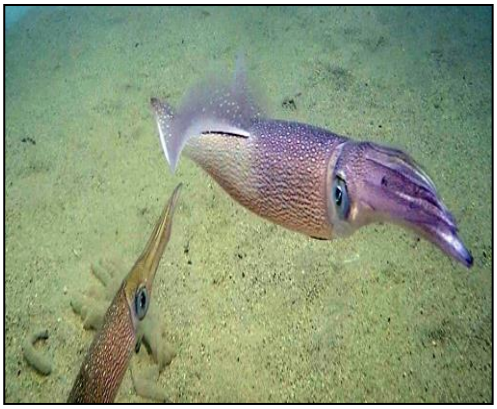

Fig. 10. *Doryteuthis pealeii*.
Image Source: https://phys.org

Conclusion

The race to explore the marine reservoirs is at its peak in the present scenario. The greed of biopirates to conquer maximum innovations and patenting them has promoted declining conditions of marine reservoirs of the globe. The biopiracy activities on the sites of marine reserves are increasing day by day behind the scientific and research explorations.

This has brought about the blurring of marine ecological diversity on a worldwide scale. This study concludes that exponential explorations of marine organisms by the global scientific communities, corporations and researchers in the search of pharmacologically active compounds have now created an alarming situation concerning environmental degradation and its ecological diversity. Through this investigation the following recommendations to safeguard the marine reservoirs from the biopirates are proposed:

- Establish and enforce global legislations to shield marine reservoirs.
- Encourage the involvement of global states towards the safeguarding of marine ecological heritage.
- Promote awareness among the local people residing near marine areas by educating them about the significance of the ocean lifeforms.
- Coordinate surveys and monitoring programmes to periodically assess the global marine reservoirs.
- Promote scientific and research explorations with a limited loss to the marine ecosystems.

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