Review

Exploring the Anti-inflammatory Potential of Mangrove Flora: A Comprehensive Review

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Exploring the Anti-inflammatory Potential of Mangrove Flora: A Comprehensive Review

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Abstract: The review explores the therapeutic potential of mangrove plants as sources of bioactive compounds, particularly focusing on their anti-inflammatory properties. Mangroves, found in tropical and sub-tropical tidal coasts, exhibit unique ecological and biological activities. The review compiles and examines 136 research findings published between 1982 and 2018, with 41 studies specifically addressing the anti-inflammatory properties of mangroves in Indian coastal regions, including the Andaman and Nicobar Islands. It summarizes the chemical structures, molecular weights, formulas, solvents, and biological activities of these mangroves, as reported by various researchers over time. The data underscore the significant potential of tropical Indian mangroves in anti-inflammatory applications. However, a notable research gap exists regarding the extraction of bioactive compounds from mangrove species in the Andaman and Nicobar Islands compared to other regions such as Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, and Puducherry. Overall, the compilation provides valuable insights into mangrove-based studies for drug discovery research, emphasizing the need for further exploration and exploitation of these natural resources.

Keywords: Bioactive compounds; mechanisms of inflammation; traditional treatment; chemical structure; mangrove plants; anti-inflammatory activity

Introduction

Neurodegeneration is a condition of neuronal death occurring as a result of gradual and progressive loss of neural cells due to the deposition of misfolded proteins such as amyloid-β (Aβ) or α-synuclein and extreme sensitivity of neuronal cells to oxidative stress achieved by the accumulation of reactive oxygen species (ROS) and reactive nitrogen species (RNS), is predominantly characterized by schizophrenia, depression, Alzheimer's disease (AD), dementia, cerebrovascular impairment, seizure disorders, head injury, Parkinsonism, anxiety and oxidative toxicity [1,2]. On the other hand, the liver, a vital organ of the human body where detoxification of a variety of drugs and xenobiotics occur, has a momentous effect on bile secretion, digestion, and metabolism. The most serious liver diseases are classified as acute or chronic hepatitis, hepatosis, and cirrhosis resulting from a viral infection, autoimmune disorder, and lipid peroxidation induced by hepatotoxic chemicals [3] No potent synthetic drugs, so far, are available that fully prevent neurodegeneration and hepatotoxicity. That's why; scientists are currently focusing on herbs and herbal medicine as an alternative source to synthetic drugs. Natural products provide molecular diversity and offer an array of lead structures useful for drug development [4–6]. A report states that from 1981 to 2014 about 50% of all new chemical entities (NCEs) were natural products or their derivatives [7,8]. Natural products and related drugs are used to treat 87% of all categorized human diseases including cancer, bacterial infection, and immunological disorders [6]. Some of the best currently known anticancer agents are derived from natural sources. The usefulness of natural products in drug discovery is indisputable. However, although several new bioactive compounds have been identified, the drug development pipeline has been drying up in recent years. Mangrove and mangrove associates have long been widely used for medicinal and non-medicinal purposes throughout the world. Plants of mangrove origin have been a source of several bioactive compounds

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and have been used in folklore medicines. There are reports of extracts from plants of mangrove origin that have proven activity against human, animal, and plant pathogens [9,10]. The diversity in the activity of these plants could be due to the peculiar environment (high moisture, large tidal difference, high salinity, an abundance of living organisms and insects, etc.) in which they exist, producing stressful conditions, that might change their morphology, physiognomy and biosynthetic pathways to survive [11–13]. Several novel bioactive chemical structures belonging to diverse chemical classes have been characterized by mangroves, and therefore, they have clinical, toxicological, and economic importance. However, the scientific information about the biological effects of these plants and active substances is scarce, and poorly documented and their active constituents remain unexplored. Mangrove plants have attracted scientists to their exorbitancy of novel compounds and thus ushered in a new era of treatment. This research is no exception to those attempts. The present study aims at screening neuroprotective and hepatoprotective activities of different organic extracts of The Sundarbans' plants to salve life-threatening ailments such as neurodegeneration and hepatotoxicity.

Medicinal Use and Biological Activity of Mangrove Plants:

India is the third richest country in the world in terms of mangrove species diversity with 46 true mangrove species belonging to 16 families and 22 genera [14], Of which, 27 species have been traditionally used against several diseases along with the Indian coastal communities (Sachithanandam et al., 2019 Unpublished data). Mangroves are a unique group of vascular plants that occur in saline coastal habitats and are known to tolerate extreme environmental conditions. Some mangrove plants are used for a wide range of conditions, including bacterial, fungal, and viral diseases. Medicinal plant extracts, known to produce certain bioactive molecules that react with microorganisms in the environment, are known to be less toxic to humans and are environmentally friendly due to fewer pollutants released during production. Mangroves and their associated plants have also been investigated for their medicinal value. Coastal communities of the Gulf of Kutch and Saurashtra use the smoked dry leaves of commonly occurring mangrove species of Avicennia officinalis for relief from asthma [15]. Another mangrove plant, Acanthus ilicifolius is useful in the treatment of paralysis, and rheumatic pains, and possesses analgesic, anti-inflammatory, and leishmanicidal activities, is a rich source of long-chain alcohols, triterpenes, steroids, and triterpenoids, saponins. Stigmasterol, a common plant steroid possessing a different chemical structure with a wide range of biological activities, is abundantly present in A. ilicifolius and many other mangrove plants shown to have Hypercholesterolemic effects [16]. The leaves and bark of Acanthus ilicifolius, a shrubby plant associated with mangrove community, is found to be useful in nervous disorders [15,17], whereas, the decoction of the plant with sugar candy and cumin is used for indigestion and also for promoting urine and as a cure for dropsy and bilious swellings [18]. The rhizome paste of Acrostichum aureum, a mangrove species is found to be useful in the case of ulcers, wounds and boils (Skin infections) [19]. Medicinally, the pounded or grated leaves and rhizomes are applied as a paste to wounds, ulcers and boils all over South-East Asia. An important mangrove associate tree species Calophyllum inophyllum, has a wide range such as in skin problems, rheumatism, swellings, ulcers, scabies, ringworm, boils, itch anti-inflammatory, antifungal, antibacterial and insecticidal activity. The paste of its seeds are applied for relief from painful joints, the oil is applied in case of rheumatism, scabies and other skin diseases camphor mixed oil is used for application on ringworms and the soap from oil has strong antibacterial and antifungicidal properties [19]. The fruits of mangrove tree - Sonneretia caseolaris are used in the preparation of poultice for sprains and swellings [20]. Kokpol et al., [21] reported, the known triterpenes, steroids, and a novel triterpenoid ester have been isolated from Acrostichum aureum and Rhizophora apiculata, a mangrove part of fern and tree, respectively. The extracts of these plants are being used in folklore medicine. In addition, A. aureum is used to treat chest pains, hypertrophy, pharyngitis, purgative and medicament pharyngitis, chest pains, hypertrophy, purgative and medicament [21]. Further, A. aureum has a widespread selection of pharmacological activities such as anti-inflammatory activity, antioxidant activity, Analgesic activity, anti-fertility activity, and cytotoxicity

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activity [23–28]. Recently, a study was performed on fresh leaves of A. marina and R. stylosa and which showed excellent sources for a large number of phytochemicals speciation [29]. Triterpenoids from R. mangle possess insecticidal properties and has clinical use in the control of diabetes [30]. Aqueous extract of the bark of R. apiculata is used as an astringent for diarrhea, nausea, vomiting and also as an antiseptic. The extract is also used to stop bleeding in fresh wounds and for the treatment of chronic typhoid fever. The plant also has been used in the textile industry [21]. S. caseolaris was found to be used traditionally to check hemorrhages, treat piles and it was also used as sprain poultices. This species was also tested for toxicity against mosquito larvae [31]. Harborne [32], reported A. marina accumulates glycine, betaine, asparagine and S. alba synthesizes purine nucleotides. It is suggested that the high levels of proline actually provide the basis of resistance to salt accumulation. Mangroves species included S. griffithii were reported to show remarkable anti-hyperglycemic activity33. The extracts from the leaves, stems, bark, and roots of mangroves species such as S. apetala have exhibited positive result for antioxidant activity test. It has also been tested for plant growth regulators, growth hormone tests on plants, and antiviral activity test [34]. Mangrove plants were studied as a promising alternative for the treatment of cigarette smoking hazardous [35]. Chemicals in cigarette smoke are a leading cause of death to both smokers and non-smokers [36]. Mangroves are a potential and novel source of anticancer drugs that regulate cancer pathways and stimulate the immune system. Medicinal research on mangroves for treatment of cancer has provided important methods for studying cancer therapy and mechanisms [36].

Inflammation:

Inflammation is a mechanism of the body which reacts to damage or diseases. Cells of the immune system migrate to the site of damage or infection and create inflammation [37]. The four symptoms of inflammation are redness, swelling, discomfort, and warmth. According to the globe Health Organization (WHO) (2018), approximately 235 million individuals suffer from inflammation in the globe. Symptomatic relief during the inflammation gives alleviation to the patients suffering from inflammatory autoimmune disorders. Although there are several anti-inflammatory medications available in the market, there is an urgent demand for improved and new anti-inflammatory treatments with reduced adverse effects and greater effectiveness. In the previous decade, the global anti-inflammatory market has been notably pushed by factors such as growing autoimmune and respiratory disorders, new medications in the pipeline, and increased use of anti-inflammatory treatments. The demand for anti-inflammatory pharmaceuticals has been growing due to the advent of anti-inflammatory bio-logics that are more targeted, effective, and with reduced adverse effects as compared to conventional/ traditional knowledge-based treatments. Further, the anti-inflammatory therapies market is estimated to gather $106.1 billion by 2020, showing a CAGR of 5.9% during the forecast period 2015-2020. WHO (2017) has re-viewed that more than 75% of the world's total population relies on herbal or plant-based medicine for their basic healthcare requirements. The majority of the world's population trusts entirely or partly on a conventional system of medicine for their fundamental health care requirements. A study done by the WHO (1993) indicated that traditional medical practitioners interact with around 90% patients in Bangladesh, 85% patients in Burma and 80% patients in India [38]. In recent years, there has been a surge in the usage of health prod-ucts derived from plants in industrialised as well as developing nations which led in the exponential expansion of herbal product globally. A increasing tendency has been noted in studies on herbal products [39]. Mangrove plant are regarded a significant component of medicinal plants and are scattered abundantly across India [40]. Mangrove plants have a significant part in the treatment of fever, sore throat, dysen-tery, kidney stone, toothache, malaria, constipation fungal infections and rheumatism [41]. Mangroves bio-active substances are viewed as a part and parcel of human civilization to battle illnesses [42]. The sche-matic graphic displays the anti-inflammatory actions of bioactive substances from traditional knowledge of mangrove plants.

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NF-κB Pathways of Inflammation:

The Nuclear Factor-κB (NF-κB) transcription factor plays significant role in inflammation, immunological re-sponse, survival and apoptotic processes. This route governs pro-inflammatory cytokine synthesis and inflammatory cell recruitment, which contribute to the inflammatory response. NF-κB represents a family of inducible transcription factors, which controls a broad set of genes involved in multiple pro-cesses of the inflammatory and immunological responses [43,44]. NF-kB is a prominent modulator of pro-inflammatory gene activities and induction in both adaptive and innate immune cells. Besides, these cells carry pattern recognition receptors (PRRs) that notice several microbial components, thus this is termed pathogen-associated molecular patterns (PAMPs) [45,46]. The numerous families of PRRs have distinct structural features and react to various PAMPs and Damage-associated molecular patterns (DAMPs), but revealed many resemblances in the downstream signal transduction pathways (Figure 3). A similar sig-naling event of the PRRs is activation of the canonical NF-κB pathway [47–50] which is responsible for transcriptional stimulation of pro-inflammatory cytokines, chemokines and supplemental inflammatory mediators in numerous kinds of innate immune cells. And so these inflammatory mediators may both direct-ly participate in the development of inflammation and performance indirectly completing stimulating the variation of inflammatory T cells [51–53]. Under varied pathophysiologic situations, activated macrophages are ca-pable of distinguishing into phenotypically distinct kinds of states, such as conventionally activated (M1) and alternatively activated (M2) macrophages [54,55]. M1 macrophages are characterized by the production of pro-inflammatory cytokines, including IL-1, IL-6, IL-12, TNF-α and chemokines, implicated in several inflammatory processes [56,57]. NF-Kb is an inducible transcription factor. After its activation, it may acti-vate the transcription of numerous genes and hence control inflammation [58]. NF-kB target inflammation not only directly by boosting the production of inflammatory cytokines, chemokines and adhesion mole-cules, but also influencing cell proliferation, death, morphogenesis and differentiation. Figure 4 displays the signaling pathways of NF-κB factors during inflammation.

Materials and Methods:

This review was carried out by gathering information on relevant research results with the use of inter-net search like Google, Google Scholar, PubMed, Sciences Direct, ResearchGate and other published arti-cles, papers and monographs. A total of 136 published publications have been studied and the associated infor-mation was acquired for this present study in regard to anti-inflammatory research efforts from Indian coastal area.

Special Focus on ANI Mangrove Resources:

ANI the biggest archipelago in India which includes of more than 572 scattered islands, islets and rocky outcrops. The overall area of the Andaman group of Islands is 6408 km2while that of Nicobar is 1841 km2. The whole coastline of the Islands is 1962 km, which accounts for 25% of the country's coastline and contains 28% of the total Indian Exclusive Economic Zone. ANI, which represents about 25% of the country's coastline are blessed with nearly one-fifth of the country's large and varied mangroves, second only to Sundarbans and Gujarat in the floristic variety. About 966 sq. km of these Islands are covered by ecologically varied mangroves or in other words, the mangroves form 10.85% of the total forest area of these Islands. As far as density and growth are concerned the mangroves in ANIs are possibly the finest in our nation. Mangroves offer vital products and services such as preserving the tropical island from erosion and provide home for various species, including economically and ecologically valuable fish and crabs.The ANI comprises of relatively vulnerable island ecosystems and consists of pure maritime environment. These habitats are incredibly diversified and sustain very distinct flora and fauna. These island groups represent a unique ecoregion and are designated as one of the 12 biogeographical zones of India by Rogers and Panwar (1988). The terrain on huge islands evolves from seagrass beds, coral reef or rocky outcrops, to beaches, littoral forest, Andaman slope forests, hilltops, valleys and streams. Of the overall forest

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cover, thick forests having crown density of 40 % represent 85. 9 % while open forests with a crown density less than 40 % form 1. 7%. Mangroves occupy 12 % of the land area of these islands. The mangrove environment belonging to the ecological sensitive regions is protected under the coastal regulatory zone (CRZ)/ Island Protection Zone (IPZ) notice 2011, in the ANI. Mangroves encompass an area of 929 km² in Andaman and in the Nicobar, the extent is 37 km² 59-60. The Islanders has been used mangroves as a source of food, medicine, fuel and at times for leisure purposes. The coastal residents on these islands depend on these ecosystems for their supplementary livelihood61. Among the 572 islands, only 38 are inhabited (population density 46 per sq km). Given the limited space, it is astounding to witness the six sorts of ethnic groups that compose the Islands' population. The inhabitants of ANI may be classified into two types : aborigines and settlers. Six native tribes dwell on these Islands. In the Andaman group of Islands, four tribes reside called Great Andamanese, Jarawas, Onges and Sentinelese, all belonging to the Negrito race. In the Nicobar group of Islands the Nicobarese and the Shompens reside, who belong to the Mongoloid race.

Traditionally Used Mangrove Plants in Tribal Areas:

An area of 513.70 km² along the west coast of South Andaman Island is classified as a tribal reserve for the Jarawa people. This reserve stretches north along the same coast onto Middle Andaman Island, increasing the reserve for another 338. 69 km². A 5 km distance into the sea from the high tide line right along the full extent of the Jarawa Reserve is also notified as part of the reserve. Strait Island, 6.01 km² in size, on the east coast of Middle Andaman Island maintains a population of 29 of the last living Great Andamanese people. the whole 24 Islands of Nicobar is notified as tribal territories; only 1, 499.65 hectares along the east coast from Campbell bay and up to 35 km is outside the Tribal Area is inhabited by ex-servicemen, merchants, gov-ernment departments and the settlers. Great Nicobar has a total area of 1044. 54 km² of which 853.19 km² is tribal reserve, both for the 380 Shompen and the Nicobarese tribes. In ANI, 38 real mangrove species be-longing to 19 taxa and 13 families have been reported (albeit without thorough distribution account, description of vegetative features and pictures). Among these, 29 are real mangroves and 14 are mangroves allied species which have been widely employed as a traditional therapy for numerous ailments in these Islands by coastal populations as well as tribal people .

Study on Anti-Inflammatory Activity of Mangrove Plants in India:

The mangrove plant extracts have been shown to be rich sources of proven activity against human, animal and plant infections and have been employed in traditional medicines [16]. Mangrove plants frequently create unique secondary metabolites under harsh situations.

Table 1. Traditionally used mangrove species in ANI coastal communities.

S. No	Name of the mangrove species	Common Name	Traditional treatment
1	*Cynometra iripa*	Wrinkle pod mangrove	Tribes extract oil from the seeds to treat against cholera
2	*Scyphiphora hydrophyllacea*	Wild Ixora	Leaf extracts are known to be helpful for stomach aches.
3	*Avicennia marina*	White mangrove/ Grey mangrove	Leaves used to treat burns. Leaves used in treatment of rheumatism, small pox, ulcers, fodder for livestock

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4	*A. officinalis*	Grey mangrove	Leaves used in treatment of smallpox, joint pain, urinary disorders, bronchial asthma, stomach disorders, hepatitis, leprosy and as an aphrodisiac, diuretic Fruits are plastered onto boils. The bark is used to treat Scabies. The cut bark oozes a green resin that is mixed with bananas and taken as a contraceptive. Seed is good for treating ulcers.
5	*Excoecaria agallocha*	Blind your eye mangrove	Treatment of epilepsy, conjunctivitis, dermatitis, haematuria, leprosy, toothache, swelling of hands and feet; flatulence; epilepsy and is anti-inflammation, uterotonic, purgative, and used as a piscicide, dart poison, skin irritant Sap as an ingredient in arrow poison using by tribal communities
6	*Bruguiera cylindrica*	Small leafed orange mangrove	Leaves are used to control blood pressure and hepatitis. Essences are extracted by squeezing the pneumatophores and used to make fragrances.
7	*B. gymnorrhiza*	Large leafed orange mangrove	Leaves used for constipation disorders Used as a medicine for eye ailment and in preparation of adhesive.
8	*B. parviflora*	Small leafed orange mangrove	The germinating embryo is used as a vegetable
9	*Pemphis acidula*	Iron wood	Bark is used as an abortifacient and stomatitis, antibacterial, antioxidant
10	*B. sexangula*	Large leafed orange mangrove	Tender leaves using for stomach pain, hypocotyls are consumed as vegetables.
11	*Ceriops tagal*	Yellow mangrove	Bark is excellent for tanning and skin related issue
12	*R. apiculata*	Tall stilted red mangrove	Astringent, antiseptic, insecticide, used for treatment of diarrhoea, nausea, vomiting, typhoid, hepatitis, and amoebiasis The bark is rich in tannin, used for tanning, dyeing and stomach pain related problems and bone fractures and joint pain cure

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13	*R. mucronata*	Long fruited stilted red mangrove	Leaves used in the- treatment of elephantiasis, haematoma, hepatitis, ulcers, and as a febrifuge and bark is-powerful astringent and used for diabetes and hemorrhage The bark is rich in tannin, used for tanning and dyeing and in the treatment of haematuria.
14	*R. lamarckii*	Spider mangrove	Leaves used in the treatment of Hepatitis
15	*Heritiera littoralis*	Looking glass mangrove	Seeds edible. Once tribes prepare a kind of tea from the leaves. Twigs are used as tooth-brush. Seeds are used in cures for diarrhoea and dysentery
16	*Lumnitzera littorea*	Black mangrove	Leaves used as a remedy for sprue
17	*L. racemosa*	Black mangrove	Anti-fertility, treatment of asthma, diabetes, and snakebite. Bark is used for tanning.
18	*Sonneratia alba*	Mangrove apple	Leaves used in the treatment of Hepatitis
19	*S. caseolaris*	Mangrove apple	Fruit is edible. Bark contains moderate amount of tannin and is used as timber. Pneumatophores are used to make wooden shoes. Stem barks using as Antioxidant agent
20	*Aegiceras corniculatum*	River mangrove	Cure for asthma, diabetes type II, rheumatism Seeds and bark contain a toxic substance named Saponin which is used as a 'fish poison', i.e., to stun fish and scoop by tribal people
21	*Xylocarpus granatum*	Cannon ball mangrove	Bark used in the treatment of fever, malaria, cholera, dysentery, insect bite Bark used for tanning
22	*X.moluccensis*	Cedar mangrove	Treat malaria fever
23	*A. ebracteatus*	Holly mangrove	Pounded seeds are used to cure boils and to treat internal worms. Leaves relieve rheumatism. Juice of leaves is reputed to prevent hair loss and fruit is pounded and used as a blood purifier and dressing for burns
24	*A. ilicifolius*	Holly mangrove	Pounded fruits are used as a blood purifier and dressing for burns. Leaves relieve rheumatism. A compress of the fruit or roots is applied in case of snake bites, kidney

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			stones, smallpox, ulcer and skin diseases. Seeds are used to treat internal worms. Also used as fodder.
25	*A. volubilis*	Holly mangrove	Powdered seeds are taken with water as a blood cleansing medicine and treatment against ulcers.
26	*Nypa fruticans*	Mangrove palm	Diabetes, snakebite Alcoholic drinks and vinegar are prepared from the sap. Fruits are eaten by local people.
27	*Phoenix paludosa*	Mangrove date palm	Anti-oxidant agent applying on wound and heat boils on face and skin
28	*A. alba*	Api-Api mangrove	Resinous substance used for birth control
29	*C. decandra*	-	Cure for hepatitis, ulcers. The bark is astringent. A decoction is used to treat haemorrhages
	Mangroves Associates		
30	*Crinum defixum*	Mangrove Lily	Traditional medicine as a purgative and for treating foot sores. Crushed leaves are mixed with honey and applied to wounds and abscesses.
31	*Drynaria quercifolia*	Oak Leaf Fern	The fresh or dried rhizome in decoction is used in haemoptysis. Leaves are used as poultices.
32	*A. aureum*	Golden Leather Fern	Pounded rhizomes are used to treat wounds and boils
33	*Flagellaria indica*	Mangrove Whip Vine	Young stems and leaves are used as shampoo to combat baldness and various medicinal applications have been reported such as using leaves as a plaster on wounds.
34	*Derris trifoliata*	Three leaved derris	The leaves contain the chemical compound rotenone, a poison that kills insects and earthworms. Rotenone clogs the gills of fishes and hence, root powder is used as a piscicide for removing weed fishes from culture ponds. The plant is also used to produce cordage
35	*Wedelia biflora*	Sea Daisy	Leaves are vulnerary and antiscabious.
36	*Abrus precatorius*	Rosary Pea	The root is used against abdominal discomfort, gonorrhoea, jaundice, tetanus and to prevent rabies.
37	*Caesalpinia bonduc*	Nicker Bean	Root is used to treat stomach pain and to stimulate the appetite.
38	*C. crista*	Fever Nut	Seeds are used to treat malaria and parasitic worms and leaves are used to treat Hepatitis -A

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39	*Cassytha filiformis*	Cascutta/Devil's Gut	Used as an anti-inflammatory. Also regularizes digestive system and induces appetite, promotes hair growth and helps in removing toxins from the body
40	*Ipomea pes-caprae*	Morning Glory	The seeds are reportedly a good remedy for stomach ache, headache and cramp. Leaves are made into a poultice and applied to swellings, bois, causes dermatitis, and ulcers. Juice of stems is used to treat bites and stings and jellyfish sting
41	*I. sepiara*	Purple Heart Glory	Seeds are used against ulcer. Juice of stems is used to treat bites.
42	*Clerodendrum inerme*	Glory Bower	Leaves - as a febrifugal and uterine stimulant, a pest control agent and antiseptic, to arrest bleeding, treatment of asthma, hepatitis, ringworm, stomach pains Used as medicine for a variety of ailments.
43	*Morinda citrifolia*	Indian Mulberry/Noni	Leaves, flowers, fruit, bark to treat eye problems, skin wounds and abscesses, gum and throat problems, respiratory ailments, constipation. Heated leaves applied to the chest relieve coughs and nausea. Juice of the leaves is taken for arthritis. The fruit is taken for asthma and dysentry. Pounded unripe fruit is mixed with salt and applied to cuts and broken bones; ripe fruit is used to draw out pus from an infected boil. Juices of over-ripe fruits are taken to regulate menstrual flow. Fruits used to treat head lice. Other exotic diseases treated with the plant include diabetes and venereal diseases.

Therefore, it is not unexpected that mangrove plants, experiencing varied ecological and environmental challenges, biosynthesize a large spectrum of secondary metabolites with potential therapeutic value [62]. The current literature search has showed that mangrove plants contain a broad spectrum of bioactive chemicals indicating anti-inflammatory effect (Tables 2 and 3). Prabhu et al. [63] reported methanolic extract of R. apiculata demonstrated anti-inflammatory action against B16F10 melanoma cells in BALB/c mice. Results demonstrated that R. apiculata extract on carrageenan-induced paw edema in non-tumor-bearing animals. The extract at 10 mg/kg Body Weight, for 10 consecutive days, revealed anti-inflammatory activities, as indicated by a re-duction in paw size at 4 h post-carageenan injection (0.39 ± 0.04 mm) compared to that observed in control (no extract) mice (0.47 ± 0.03 mm) group animals on the same hour. Krishnamoorthy et al. [64], studied antiox-idant activities of two Indian mangrove plants B. cylindrical and C. decandrai collected from Pichavaram mangroves and they extracted total phenolics and total flavonoid compounds which showed strong antioxi-dant activities than that of the reference standard, butylated hydroxyl toluene (BHT). Kumar et al. [65], re-vealed an anti-inflammatory activity of methanolic leaf derived from A. ilicifolius taken from Sundarban mangrove habitat, which strongly inhibited both COX 1(1g/ml; 99%) and COX 2 (1g/ml; 87%) enzymes. However, the typical medications such as acetylsalicylic acid (18 g/ml) exhibited 97% inhibition of COX 1 while that of

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rofecoxib (3.14 g/ml) was shown to be 95% for COX 2. The chloroform ex-tract of R. carrageenan leaves was found to contain two anti-inflammatory chemical Olean-18(19)-en-3β-yl-(3, 6-dimethyl-3E, 6Z-dienoate) and (13α)-27-frido-olean-14(15)-en-(17α)-furanyl-3β-ol. The fraction CF4 produced following the chromatographic fraction of the crude demonstrated considerably stronger COX2 (IC501. 15mg/ml) and 5-LOX (0.87mg/ml) inhibitory activity than the crude (IC50 1.38 and 1.16 mg, respective-ly). Further, CF10 demonstrated COX-2 (IC50 1.36mg/ml) and 5-LOX (IC50 0.98mg/ml) and compared to other CF12 displayed COX-2 (IC50 1.12mg/ml) and 5-COX (IC50 0.90mg/ml) as the possibly sub-fraction pos-sessing considerably better anti-inflammatory activities66. Raola et al.67 demonstrated that the methanolic leaf extract of R. mucronata exhibited two terpenoids one with an extended Guaiane Sesquiterpenoid and other with C40 prenylated oleanane-type triterpenoid which is frame-work with the antioxidant and anti-inflammatory effects. The methanol extract of R. mucronata of Kundapur coast, Karnataka at a dose-dependent 250 and 500mg/kg (b.w) possess significant anti-inflammatory activity in formalin-induced paw edema, sub-acute sponge pellet induced inflammation and chronic adjuvant-induced arthritis – immunolog-ical method in rats. The extracts were determined to be harmless in acute toxicity testing [68]. Babuselvam et al. [69], discussed an anti-inflammatory activity of latex, leaves and seeds extracts of two concentrations of E. agallocha mangrove sample collected from Pichavaram mangrove ecosystem, produced a significant inhi-bition of carrageenin-induced rat paw edema at 3rd hour ($p< 0.005$) as compared to the control groups (rats), causing 62.15%, 63.15%, and 69.69% respectively. Intraperitoneal injection of aspirin (100mg/Kg) induced dose-dependent reduction of edema. Crude extracts of latex, leaves and seed of E. agallocha (250, 500mg/kg), the extracts of latex (250 mg/kg, IC50 55.26; 500mg/kg, IC50 57.89), leaves (250 mg/kg, IC50 52.63; 500mg/kg, IC50 60.52) and seed (250 mg/kg, IC50, 55.16; 500mg/kg, IC50, 60.61) exhibited sig-nificant ($P<0.01$) reductions in paw edema volume of rats and standard drug aspirin (100mg/Kg) showed decreased granuloma tissue and increased percentage of inhibition. Kumari et al.70 dealt with meth-anolic leaf extract of R. mucronata of southeast coast of India, which notably demonstrated anti-inflammatory action at the concentration of 400 mg equivalent to the conventional medicine diclofenac sodium. There was a comparable investigation done by Ray et al. [71], who gathered mangrove samples of Sundarban mangrove environment and observed that R. mucronata leaves displayed an in-vitro anti-inflammatory activity in RAW264.7 cell line by MTT test. The impact of the ethanolic extract of R. mucronata leaves (25, 50, 100, 200 and 400μg/ml) on the viability of unstimulated RAW264.7 cells was examined using the MTT assay. Treatment with RME analysis exhibited no significant decrease of cell growth, showing these dosages were non-toxic to RAW264.7 cells.

Table 2. Anti-inflammatory properties of bioactive compounds from Indian mangroves.

S. No.	Chemical structure	Description	Reference
1	Olean-18(19)-en-3β-yl-(3, 6-dimethyl-3E, 6Z-dienoate)	Source: *R. mucronata* (Leaf) Mole. For: $C_{40}H_{64}O_2$ Mol. Wt: 577.4992 Solvent: Methanol Biological activity: Anti-inflammatory	[66]

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2.	(13α)-27-frido-olean-14(15)-en-(17α)-furanyl-3β-ol	Source: *R. mucronata* (Leaf) Mole. For: $C_{33}H_{50}O_2$ Mol. Wt: 479.3890 Solvent: Methanol Biological activity: Anti-inflammatory	[66]
3	4E, 8Z)-3, 3a, 6, 7-tetrahydro-3, 9-dimethyl-5-(6-methylheptan-2-yl) cycloocta[b]	Source: *R. mucronata* (Leaf) Mole. For: $C_{20}H_{32}O_2$ Mol. Wt: 304.2638 Solvent: Methanol Biological activity: Anti-inflammatory	[67]
4.	(35E)-1, 2, 3, 5, 6, 6-icosahydro-4, 4, 8b, 10, 14, 17, 20, 20-octamethylpicen-3-yl-34, 35-dimethyloct-31-enoate	Source: *R. mucronata* (Leaf) Mole. For: $C_{40}H_{66}O_2$ Mol. Wt: 579.5264 Solvent: Methanol Biological activity: Anti-inflammatory	[67]
5.	Ovaliflavanone	Source: *D. scandens* (Leaf) Mole. For: $C_{25}H_{28}O_3$ Mol. Wt: 376.496 Solvent: Chloroform Biological activity: Anti-inflammatory	[133]
6.	Lupinifolin	Source: *D. scandens* (Leaf) Mole. For: $C_{25}H_{26}O_5$ Mol. Wt: 408.49	[133]

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		Solvent: Chloroform Biological activity: Anti-inflammatory	

Table 3. Anti-inflammatory properties of pure bioactive compounds from Worldwide mangroves.

S. No.	Chemical structure	Description	Reference
1.	Agallochaol K	Source: *E. agallocha* (Stem and Twigs) Mole. For: $C_{20}H_{30}O_3$ Mol. Wt: 341.2096 Solvent: Ethanol Biological activity: Anti-inflammatory	[128]
2.	Agallochaol O	Source: *E. agallocha* (Stem and Twigs) Mol. For: $C_{29}H_{36}O_5$ Mol. Wt: 487.2458 Solvent: Ethanol Biological activity: Anti-inflammatory	[128]
3.	Agallochaol P	Source: *E. agallocha* (Stem and Twigs) Mole. For: $C_{20}H_{30}O_3$ Mol. Wt: 318.46 Solvent: Ethanol Biological activity: Anti-inflammatory	[128]
4.	Agallochaol Q	Source: *E. agallocha* (Stem and Twigs)	[128]

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		Mole. For: $C_{20}H_{36}O_2$ Mol. Wt: 325.2140 Solvent: Ethanol Biological activity: Anti-inflammatory	
5.	ent-17-hydroxykaur-15-en-3-one	Source: *E. agallocha* (Stem and Twigs) Mole. For: $C_{20}H_{30}O_3$ Mol. Wt: 318.457 Solvent: Ethanol Biological activity: Anti-inflammatory	[128]
6.	ent-kaur-15-en-3b	Source: *E. agallocha* (Stem and Twigs) Mole. For: $C_{20}H_{30}O_2$ Mol. Wt: 302.458 Solvent: Ethanol Biological activity: Anti-inflammatory	[128]
7.	17-diol, ent-15, 18-dihydroxylabd-8, 13E-diene	Source: *E. agallocha* (Stem and Twigs) Mole. For: $C_{21}H_{34}O_2$ Mol. Wt: 318.50 Solvent: Ethanol Biological activity: Anti-inflammatory	[128]
8.	Ergosterol peroxide	Source: *H. littoralis* (Bark) Mole. For: $C_{28}H_{44}O_3$	[129]

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		Mol. Wt: 428.657 Solvent: Hexane and acetone Biological activity: Anti-inflammatory	
9.	6-α-hydroxystigmast-4-en-3-one	Source: *H. littoralis* (Bark) Mole. For: $C_{29}H_{48}O_2$ Mol. Wt: 428.7 Solvent: Hexane and acetone Biological activity: Anti-inflammatory	[129]
10.	Stigmast-4-en-3-one	Source: *H. littoralis* (Bark) Mole. For: $C_{29}H_{48}O$ Mol. Wt: 412.702 Solvent: Hexane and acetone Biological activity: Anti-inflammatory	[129]
11.	Eugenol	Source: *I. pes-caprae* (Leaf) Mole. For: $C_{10}H_{12}O2$ Mol. Wt: 164.2 Solvent: Petroleum ether Biological activity: Anti-inflammatory	[127]
12.	4-vinyl-guaiacol	Source: *I. pes-caprae* (Leaf) Mole. For: $C_9H_{10}O_2$ Mol. Wt: 150.177 Solvent: Petroleum ether Biological activity: Anti-inflammatory	[127]

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13.	3-γ, γ- dimethylallylweighteone,	Source: *D. scandens* (Stem) Mole. For: $C_{25}H_{26}O_5$ Mol. Wt: 406.48 Solvent: Water Biological activity: Anti-inflammatory	[126]
14.	Scandium	Source: *D. scandens* (Stem) Mole. For: $C_{26}H_{26}O_6$ Mol. Wt: 434.488 Solvent: Water Biological activity: Anti-inflammatory	[126]
15.	Genistein	Source: *D. scandens* (Stem) Mole. For: $C_{15}H_{10}O_5$ Mol. Wt: 270.241 Solvent: Water Biological activity: Anti-inflammatory	[126]

An noteworthy anti-inflammatory action was identified in fruit the body of S. alba which displayed a greater activity in membrane stability, protein denaturation and protease inhibition. Finally, the findings revealed that, among the chosen portions of mangroves ethanolic fruits extracts of S. alba obtained from Bhatye beach region situated at Ratnagiri district, Maharastra coast demonstrated more strong anti-inflammatory effects [72]. Recently, a silver nanoparticle produced study was carried out to identify the anti-inflammatory chemicals from A. marina mangrove samples, taken from the Muthupet mangrove. The leaf extracts of A. marina which demonstrated anti-inflammatory action, protein denaturation inhibitory, anti-proteinase inhibitory activity [73]. Comparative investigations of anti-inflammatory efficacy of crude extracts of several mangrove plants in national and international levels are presented in Tables 4 and 5.

Table 4. Anti-inflammatory activities of crude extracts produced from mangrove plants in India.

Sl. No	Family	Name of the plant	Plant parts	Activity	References

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1.	Acanthaceae	*A. ilicifolius*	Leaf extract	Anti-inflammatory	[65,83]
2.	Euphorbiaceae	*E. agallocha*	Leaf and Seed extract	Anti-inflammatory	[69]
3.	Fabaceae	*Pongamia pinnata* *P. pinnata*	Leaf extract Seed extract	Anti-inflammatory Anti-inflammatory	[130–132]
4.	Lythraceae	*S. alba*	Fruit extract	Anti-inflammatory	[71]
5.	Acanthaceae	*A. marina*	Leaf extract	Anti-inflammatory	[73]
6.	Rhizophoraceae	*R. mucronata* *R. apiculata*	Whole plant extract; Leaf; Bark	Anti-inflammatory	[63,66–68,70,72]
7.	Fabaceae	*D. scandens*	Leaf and Root	Anti-inflammatory	[134]

Table 5. Anti-inflammatory activities of crude extracts produced from mangrove plants in Worldwide.

Sl. No	Family	Name of the plant	Plant parts	Activity	References
1.	Myrsinaceae	*A. corniculatum*	Stem extract	Anti-inflammatory	[112]
2.	Lecythidaceae	*B. racemosa*	Leaf extract	Anti-inflammatory	[134]
3.	Leguminosae	*C. mimosoides*	Root extract	Anti-inflammatory	[135]
4.	Euphorbiaceae	*E. agallocha*	Stem extract	Anti-inflammatory	[128]
5.	Tamaricaceae	*Tamarix indica*	Root extract	Anti-inflammatory	[39]
6.	Fabaceae	*D.scandens*	Stem extract	Anti-inflammatory	[126]

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7.	Convolvulaceae	*I. imperati* *I. pes- caprare*	Leaf extract	Anti-inflammatory	[127,136]
8.	Sterculiaceae	*H.littoralis*	Bark extract	Anti-inflammatory	[129]
9.	Rhizophoraceae	*C. decandra*	Bark extract	Anti-inflammatory	[24]
10.	Asteraceae	*Launaea sarmentosa*	Stem, bark and leaf extract	Anti-inflammatory	[98]
11.	Plumbaginaceae	*Aegialitis rotundifolia*	Stem, bark and leaf extract	Anti-inflammatory	[98]
12.	Myrsinaceae	*A. corniculatum*	Stem	Anti-inflammatory	[111]
13.	Acanthaceae	*A. marina*	Leaf extract	Anti-inflammatory	[102]

Status of Biological Study Using Marine Flora in ANI:

Mangrove plants have been employed for their therapeutic characteristics by the coastal inhabitants of India for the treatment of inflammation, painful arthritis, antioxidant, diabetes, hepato-protective activities, asthma, tu-mor, rheumatism, anti-nociceptive and antipyretic activity [63–66,71]. However, in the Indian environment, on-ly restricted investigations have been undertaken for the separation and purification of bioactive chemicals from mangroves plants. ANI are blessed with rich marine biodiversity/ mangroves plants, relatively few research have been undertaken out to examine the marine bioactive chemicals from these Islands. There are little investigations con-ducted in ANI for the antibacterial activity (multi-drug resistance) of Vibrio harveyi and V. compel-lii against leaf extract of R. mucronata of mangroves plants [74]. Chander et al. [75], found that the metha-nol extract of seaweed, Padina gymnospora collected from South Andaman island showed antimicrobial activity against selected human pathogens namely E. coli, S. aureus, S. epidermidis, B.cereus, S. typhi, S. flexneri, P. aeruginosa, K. pneumoniae, P. mirabilis, Candida albican and Aspergillus niger. Bacillus sub-tilis and Bacillus thuringiensis subspisrae lensis isolated from Andaman mangroves by Geeth et al. [76], showed mosquitocidal activity against the larvae and pupae of Anopheles stephensi, Culexquinque fascia-tus and Aedesae gypti. Suman et al. [77] isolated Pseudoceratina purpurea from ANI possessed secondary metabolites which showed antibacterial activities against Klebsiella pneumonia and B. licheniformis. B. licheniform (related bacteria) obtained from the marine sponge from ANI exhibited the potential of sur-factant for application in bioremediation of hydrocarbons in a marine environment and for increased oil recovery.

Research Gap:

The purpose of this review study was to examine the present state on research relevant to anti-inflammatory of mangroves from context and to advise for future investigations. Based on the literature assessment it is observed that, there is extensive research on mangroves plants with specific

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reference to anti-inflammatory substances needs to be investigated from coastal areas of India [66](Table 6).

Table 6. Statewise estimate of mangroves.

S.No.	States/ UT	Areas (Sq. Km.)
1	Gujarat	1, 140
2	Maharashtra	304
3	Goa	26
4	Karnataka	10
5	Kerala	9
6	Tamil Nadu	49
7	Andhra Pradesh	404
8	Odisha	243
9	West Bengal	2, 114
10	ANI	617
11	Puducherry	2
12	Diu and Daman	3
	Total	4, 921

There is a major vacuum in study effort on anti-inflammatory studies on mangroves plants of India which also comprise ANI. Research gap detected on the basis of descriptive analysis displayed in Figure 6. Descriptive analysis data revealed that majority of the research were done in Tamil Nadu coast, followed Andhra Pra-desh, Odisha, West Bengal, Gujarat and Karnataka. However, along with other studies, in ANI there is a need for launching more study work on anti-inflammatory since there are no reports for the same from the pristine environment. Henceforth, this brief study presents an insight into the research efforts that have been undertaken for the isolation and identification of anti-inflammatory chemicals from mangroves plants in India. This sort of review study helps to extend the current information on a crucial issue like anti-inflammatory and associated drug development for the future investigations.

Conclusions

This study evaluated the traditional usage and their bioactive potential of mangrove plants. The pharma-cological potential of the mangroves from Indian area still remains substantially untapped notably from island habitat of ANI. This review shows that, the mangrove species of Rhizophora sp., Acanthus sp., Excoecaria sp., Sonneratia alba., and Avicennia sp., are considered to be the highly potential candidates for the blockbuster of anti-inflammatory activities against skin diseases, gastrointestinal disorders, fungal infections, and hepatitis, etc., and they have been reported for the various pharmacological activities including chronic inflammatory of anticancer, antifungal,

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antibacterial and anti-diabetic activities. However, there is a need for commencing the systematic research study on biological im-portance, notably anti-inflammatory effects of mangroves species of ANI, as it is regarded as an un-touched and unexplored field of above-mentioned study.

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