VOLUME 8 ISSUE 1 2022

ISSN 2454-3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 8, No. 1, 421-433 (2022)

International Journal of Zoological Investigations
Contents available at Journals Home Page: www.ijzi.net
Editor-in-Chief: Prof. Ajai Kumar Srivastav
Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Importance of Mangroves to Human Well-being

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Received: 7th March, 2022; **Accepted:** 30th March, 2022; **Published online:** 8th April, 2022

https://doi.org/10.33745/ijzi.2022.v08i01.047

Abstract: Mangroves and their associated biodiversity help to deliver important goods and services that play a critical role in supporting human well-being through climate regulation, food security and poverty reduction. This review focuses on importance of mangroves to human with respect to: (i) definition; (ii) categories; (iii) provisioning services; (iv) regulating and supporting services; (v) recreational, spiritual and cultural services and (vi) quantifying mangrove values. The study recommends protection and sustainable management of remaining mangrove ecosystems, successful restoration using sound scientific protocols and to allocate mangrove resources to improve human well-being.

Keywords: Mangrove, Ecosystem services, Human well-being, Restoration, Sustainable management

Citation: Naik Mayur S. and Pawar Prabhakar R.: Importance of mangroves to human well-being. Intern. J. Zool. Invest. 8(1): 421-433, 2022.
https://doi.org/10.33745/ijzi.2022.v08i01.047

Introduction

Mangroves are a type of tropical forest, uniquely positioned at the dynamic interface of land and sea, found along coasts and estuaries throughout the tropics and subtropics and are capable of thriving in salt water. Increasing recognition of the importance of mangrove ecosystems for both biodiversity and human well-being is driving efforts around the world to conserve, better manage and restore these ecosystems (UNEP, 2014). Mangroves are woody plants in the coastal wetland ecosystem with both terrestrial and marine properties, which can provide a variety of important goods and services to humanity (Rovai *et al.*, 2018).

Mangroves have played an important role in the economics of coastal population for thousands of years, providing a variety of goods and services (Satheeshkumar *et al.*, 2012), and are treasured storehouse of the nature (Maiti and Chowdhury, 2013). van Bijsterveldt et al (2021) stated that mangrove forests provide multiple provisioning, regulating and recreational ecosystem services. Sen (2019) reported that Sundarbans (the world's largest single mangrove forest and the UNESCO Marine World Heritage-listed) between Bangladesh and India, and its resources provide provisional (genetic resources, food and fiber, fuel wood, etc.) services directly and indirectly to 3.5

million people of Bangladesh for their livelihood.

According to Hamilton and Casey (2016), mangrove forests cover about 132,000 km^2 along subtropical and tropical shores. Global mangrove area currently equals about 15.2 million hectares with the largest area found in Asia and Africa, followed by North and Central America (Friess *et al.*, 2019). India has only 2.66% of the world's mangroves covering an estimated area of 4827 km^2 (Satheeshkumar *et al.*, 2012). Sahu *et al.* (2015) reported that mangrove cover in India is 4,975 Km^2 (1.2 million acres), which is 0.15% of the country's geographical area. West Bengal has 42.45% of India's mangrove cover, followed by Gujarat 23.66% and Andaman and Nicobar Islands 12.39%. Mangroves are structurally complex iconic ecosystems, which cover an area of 66 km^2 in Mumbai (Kantharajan *et al.*, 2018).

The present review provides an overview of the ecosystem goods and services of mangroves to human with respect to definition, categories, types, quantification, provisioning services, regulating and supporting services and recreational, spiritual and cultural services.

1. *Threat to mangroves*:

UNEP (2014) recorded that in spite of the mounting evidence in support of the multitude of benefits derived from mangroves, they remain one of the most threatened ecosystems and continue to be cleared at an alarming rate. An alarming 20%, or 3.6 million hectares of mangroves have been lost since 1980 (Friess *et al.*, 2019). Satheeshkumar *et al.*, (2012) pointed that the major reasons for destruction of mangroves are urban development, mining, agriculture, overexploitation for timber, aquaculture and overfishing along with massive pressure from clear-cutting, encroachment, hydrological alterations, fertilizers and pesticides, oil spills, storms and climate change.

Widespread occurrence of plastics and other waste materials such as bottles, tyres, thermocol, foot wears, abandoned fishing nets and glass pieces in the mangrove areas is detrimental to the coastal environment at Juhu, Gorai and Versova of Mumbai (Kantharajan *et al.*, 2018). Mangrove forests continue to decline due to numerous anthropogenic stressors such as plastic waste (Adyel and Macreadie, 2021; Naik *et al.*, 2021; van Bijsterveldt *et al.*, 2021); coastal development (Maiti and Chowdhury, 2013); microplastics (John *et al.*, 2021); marine debris (Martin *et al.*, 2019; Li *et al.*, 2021) and urban expansion and human settlement (Goldberg *et al.*, 2020).

2. *Ecosystem Goods and Services of Mangroves*:

2.1 *Definition of Mangrove Ecosystem Goods and Services*:

The ecosystem services are the benefits that ecosystems provide to human populations (Friess, 2016). Mangroves deliver a range of economic, social and environmental benefits to people, collectively referred to as their 'ecosystem goods and services' (UNEP, 2014).

Mangrove ecosystems present an exclusive and expensive assortment of resources, services and to confident extent products (Vinoth *et al.*, 2019). It is vital for resources and income to people living in proximity to mangroves. About 120 million people are living within 10 km of significant mangrove areas and many of them are heavily reliant on these mangroves for their daily sustenance and well-being (UNEP, 2014).

2.2 *Categories of Mangrove Ecosystem Goods and Services* :

Ecosystem services provided by mangroves are divided into three broad categories such as provisioning services, regulating and supporting services and recreational, spiritual and cultural services (Table 1).

2.3 *Types of Mangrove Ecosystem Goods and Services*:

Mangroves support primary and secondary production in nearshore waters, mitigate climate change through sequestration of CO_2, and protecting human communities from devastating storms and tsunamis (Kangkuso *et al.*, 2019). They provide access to basic materials health, security and good social relations (Spalding *et al.*, 2010).

Table 1: Ecosystem goods and services provided by mangroves (UNEP, 2014)

Provisioning services (Goods that people obtain from ecosystems)	**Regulating and Supporting services** (Regulation of ecosystem processes, climate and maintenance of healthy coastal ecosystems)	**Recreational, Spiritual and Cultural services** (Non-material benefits obtained from mangroves)
Biodiversity	Climate regulation	Aesthetics
Fibre	Coastal protection	Ecotourism
Fisheries	Nutrient cycling	Education
Fodder	Provision of nursery habitats	Heritage and culture
Food	Soil stabilisation and erosion control	Recreation
Fuel wood materials	Support to coral reefs, sea grass beds, mud flats and sand flats	Religious value and cultural ceremony
Medicine	Water cycling	Scientific research
Tannin	Water quality maintenance	Spiritual enrichment
Timber and construction		

Mangroves provide goods in the form of wood for construction, fuelwood, charcoal, furniture, fish traps, as well as non-timber forest products such as honey, fruit, medicine, wine and palm thatch for roofing (UNEP, 2014).

Mangroves provide an essential source of seafood and materials such as fuelwood, timber and forest products to support the livelihoods of millions of people (Kangkuso et al, 2019). The complex network of mangrove roots help reduce wave energy, limiting erosion and helping to shield coastal communities from the destructive forces of tropical storms and tsunamis. Mangroves help to maintain water quality and regulate our climate by the uptake of pollutants, cycling of nutrients and sequestration and long-term storage of carbon (Vinoth *et al.*, 2019).

2.4 *Quantifying Mangrove Values*:

The values of ecosystem services provided by mangroves can be expressed qualitatively, in quantitative terms or by economic valuation studies (UNEP, 2014).

- *Qualitatively*: Relative regional importance of cultural heritage derived from mangroves to people.
- *Quantitative terms*: Amount of carbon stored in a mangrove forest. Values can be expressed in monetary (economic) terms, such as the market value of mangrove fisheries or timber.
- *Economic Valuation Studies*:

(i) *Arabian Gulf region*: Mangroves are relatively rare but culturally important habitat and have much higher non-market value.

(ii) *Region with plenty of mangroves*: Mangroves are plentiful and goods originating from them are in relatively abundant supply. Monetary values taken as indicative.

3. *Provisioning ecosystem services of mangrove* (*Goods that people obtain from mangrove ecosystems*):

Mangroves provide goods in the form of wood for construction, fuelwood, charcoal, furniture, fish traps, as well as non-timber forest products such as honey, fruit, medicine, wine and palm thatch for roofing (UNEP, 2014).

3.1 *Biodiversity*:

Mangroves represent a rich and high diverse natural resource and acts as a home to many uniquely adapted biodiversity (IUCN, 2006). Rao (1987) stated that mangrove provides species habitat to 193 plant species, 397 fish species, 259 crab species, 256 mollusc species, 450 insects and more than 250 species of mammals. Many diverse species inhabit mangrove forests, including spiny

lobster, reef fish (grunts and snappers), fish, birds, reptiles, amphibians, molluscs, crustaceans, algae, sponges, corals, anemones, clams, sea snails, mussels and crabs. Coastal birds, such as pelicans, spoonbills and ospreys, use the mangrove canopy for nesting, roosting and feeding (Christine, 2005). IUCN (2006) recorded that species of manatees, monkeys, fishing cats, monitor lizards, sea turtles, and mud-skipper fish use the mangrove wetlands as their habitat. Kathiresan (2000) cited that the Pichavaram mangroves alone nurture 30 species of prawns, 30 species of crabs, 20 species of molluscs, and 200 species of fish. Eight futuristic habitats of mangrove provides habitat for diverse species of bacteria, fungi, macro algae, planktons, larval forms, insects, crabs, shrimps, crabs, molluscs, demersal and pelagic fishes, frogs, reptiles, birds and mammals (Govindasamy, 2011). UNEP (2014) noted that commercially important fish species such as snapper, mullet, wrasse, parrotfish, sharks and rays utilise mangroves during all or part of their lives, with the mangrove providing critical food, shelter and refuge functions.

3.2 *Fisheries*:

Christine (2005) noted that mangrove forests are used as harvesting areas for fish, shrimp, lobster, mussels and other molluscs. Mangrove ecosystems are important for fish production as they serve as nursery, feeding and breeding grounds for many fishes and shellfishes (Kathiresan, 2012). Mangrove habitats support fisheries; from subsistence foraging in the mangrove itself, to industrialised, commercial offshore fisheries (UNEP, 2014). Mangrove fisheries provide an accessible source of protein, employment and income and emergency food provision to coastal community. Some species of mangrove associated snails and bivalves are readily harvested when there is no other food available to a household (Crow and Carney, 2013).

One of the important ecological service of mangroves is the support to off-shore fisheries by serving as a breeding ground (IUCN, 2006). The storm buffering capacities of mangroves can safeguard fishing grounds and protect fishing harbours from the ravages of extreme weather events (Williams *et al.*, 2007). The complex mangrove habitat provides refuge from predation to shellfish and crustaceans and also forms ideal attachment points for many animals, including species of oyster. The soft muddy floor of mangrove ecosystem provide habitat for mangrove clams, prawns and crabs. The steady supply of falling leaves and detritus from mangroves provide an abundant supply of food for crab, snail and fish (UNEP, 2010).

3.3 *Fodder*:

In Kutch, the mangrove fodder remained entire diet of camel, goats, sheep and other milking animals (Untawale, 1985). According to Vannucci (1989), in Sundarbans and Andaman-Nicobar islands, the animals including deer feed upon *Avicennia* sp., *Heretiera fomes* and *Nypa fruticans*. Baglo (2005) noted that in Republic of Benin, parts of mangroves such as leaves, grass and pods were harvested as fodder and sold or preserved for the dry season. Mangrove leaves are used as animal fodder for buffaloes, sheep, goats and camels (Govindasamy and Kannan, 2012). Kathiresan (2012) reported that mangroves especially *Avicennia* form cheap and nutritive feed for buffaloes, sheep, goats and camels. In northeast Africa, the Middle East, Pakistan and Egypt, leaves of *Avicennia marina* are extensively used as fodder for camel and goats (FAO, 2012).

Sathe *et al.* (2015) documented that in Malvan Tahsil of Maharashtra, three species of *Avicennia* are widely used as fodder to the cattle in summer during scarcity of green fodder. Baba *et al.* (2016) recorded that in Gujarat, India, the foliage of *Avicennia marina* was used as fodder and forage for the cattle. In Republic of Benin (West Africa), *Rhizophora racemosa*, *Avicennia africana*, *Paspalum vaginatum*, *Zanthoxylum zanthoxyloides* and *Blutaparon vermiculare* were used for feeding the ruminants in the surrounding meadows (Teka *et al.*, 2012; Bidossessi *et al.*, 2021).

In Indonesia, mangrove foliage is commonly

known to feed the domestic animals such as cattle, goats, sheep and buffaloes (Kusmana and Sukristijiono, 2016). Use of mangroves as fodder and forage for cattle in dairy farms was also reported by Khafaji *et al.* (1993) in Saudi Arabia, PERSGA (2004) in the Red Sea and Gulf of Aden in New Zealand by Maxwell and Lai (2012).

3.4 *Food*:

One of the immediate benefits of mangrove forests is a source of food (Patil and Chavan, 2013). Food products can be prepared from the fruits, flowers and leaves of mangrove (Situmorang and Barus, 2015). Satuhu (2004) noted that in Indonesia, parts of mangrove are utilized for synthesis of food products such as leaves (green tea, chips and beverages) and fruits (Cake, cookies, juice, syrup, jam, flour, fresh drink, alcoholic drink, brown sugar and various cakes).

Govindasamy (2011) documented that mangrove forest provide important direct and indirect food items (fish, meat etc.). In Southeast Asia and Columbia, seeds of *Avicennia* and *Nypa* are consumed. In Malaysia and Indonesia, young leaves and the seeds of *Sonneratia* are boiled as vegetable and in Thailand, people eat the root tips of *Buguiera* and make salad out of leaf shoots of *Cosperma*.

Semarang (2013) pointed that in Indonesia, various mangrove species has been used as food in traditional manner such as *Bruguiera gymnorrhiza* (to make cake, mixed by rice, eating directly with coconut); *Avicenia alba* (eating directly with coconut, cracker); *Soneratia alba* (for syrup and drinks), *Rhizopora mucronata* and *Acrosticum aerum* (for vegetables) and *Bruguiera gymnorrhiza* (improve food potency due to high carbohydrate content). Dahdouh-Guebas (2013) recorded that mangrove species are the source of food and drinks such as fruit juice, ice cream, marmalade (*Sonneratia caseolaris*), tea (*Avicennia germinans, Bruguiera cylindrica, Ceriops decandra, Rhizophora apiculata, R. lamarckii* and *R. mucronata*), alcohol (*Nypa fruticans*), vegetables (*Avicennia marina, Bruguiera* spp.), salad (*Acrostichum aureum*) and cakes and pastries (*Bruguiera gymnorrhiza, Kandelia candel*).

Friess *et al*. (2019) observed that mangrove propagules such as *Avicennia* can be used as a food source by boiling for a few days to reduce bitterness. Kangkuso *et al*. (2019) observed that mangrove fruits have basic ingredients useful for the growth, development and intelligence of human. Fruits of *Xylocarpus granatum*, *Sonneratia alba* and *Bruguiera gymnorrhiza* growing in the RAWN Park, Southeast Sulawesi, Indonesia are a potential source of bio-nutrients (sugar, protein, fat, beta-carotene and ascorbic acid), antioxidants, macronutrients (Na, K and Ca) and micronutrients (Fe, Cu, Mn and Zn).

3.5 *Fuel wood materials*:

Wood of many species of mangroves is very dense and release high heat when burned. Mangrove charcoal is among the heaviest charcoals and is the mainstay for cooking fires and smokehouses in Asia, Africa and many islands in the Pacific (Nagelkerken, 2009). Dahdouh-Guebas *et al*. (2000) stated that due to its high calorific value, mangrove species like *Rhizophora* is highly valued as firewood. The wood of *Avicennia marina* was used to fuel rudimentary kilns to burn invertebrate shells to create a lime render for house walls in East Africa.

According to UNEP (2014), wood of *Avicennia germinans*, *Conocarpus erectus*, *Laguncularia racemosa*, *Lumnitzera* spp., *Rhizophora* spp. *Rhizophoraceae*, *Sonneratia* spp. and *Xylocarpus* spp., is commonly used as fuel wood materials. In villages the folks are dependent on mangroves for firewood. The best charcoal with highest caloric power, exceptional slow-burning properties and no smoke is obtained from *Rhizophora* billets (Vinoth *et al*., 2019).

3.6 *Medicine*:

Vinoth *et al*. (2019) stated that substances in mangroves have been used in folk medicines to treat diseases. Extracts of various parts of mangroves have significant activity against animal, human, and plant viruses including human

Table 2: Medicinal uses of mangroves (Vinoth *et al*., 2019)

S. No.	Species of mangrove	Uses in treatment
1	*Acanthus ilicifolius*	Cough, asthma, leucorrhoea, paralysis, dyspepsia, hepatitis, leprosy and rheumatic pains.
2	*Aegiceras corniculatum*	Asthma, diabetes, rheumatism and fish poisoning.
3	*Avicennia marina*	Skin diseases.
4	*Avicennia officinalis*	Aphrodisiac, diuretic, hepatitis and leprosy.
5	*Bruguiera gymnorhiza*	Eye diseases
6	*Bruguiera parviflora*	Antitumor
7	*Ceriops decandra*	Hepatitis and ulcers
8	*Excoecaria agallocha*	Epilepsy, conjunctivitis, dermatitis, hematuria, leprosy, toothache, mosquito borne diseases and pandemic diseases.
9	*Lumnitzera racemosa*	Anti-fertility, asthma, diabetes and snake bite
10	*Rhizophora apiculata*	Diarrhoea, nausea, vomiting, antiseptic, anti-hemorrhagic, typhoid fever and diabetics.
11	*Rhizophora mangle*	Angina, boils, fungal infections, antiseptic, diarrhoea, dysentery, elephantiasis, fever, malaria, leprosy, minor bruises, fractured bones and tuberculosis.
12	*Rhizophora mucronata*	Elephantiasis, haematoma, hepatitis and ulcers.
13	*Salicornia brachiate*	Hepatitis
14	*Sesuvium portulacastrum*	Hepatitis
15	*Sueda maritima*	Hepatitis
16	*Sueda monoica*	Hepatitis

immunodeficiency virus. Mangrove leaves contain phenols and flavonoids that serve as ultraviolet (UV) screen compounds. Several species of mangrove produce bioactive compounds that may control microbial growth.

Bioactive compounds from mangroves (*phytochemicals*):

Bandaranyake (1995) reported that secondary metabolites from mangroves (carbohydrates, alcohols, amino acids, fatty acids, lipids, phenolic compounds, steroids, glycosides, triterpenes, steroids, saponins, flavonoids, alkaloids, tannins, gums, glues to alkaloids and saponins) have toxicological, pharmacological and ecological importance. Mangroves such as *Acanthus ilicifolius*, *Aegiceras corniculatum*, *Avicennia marina*, *Excoecaria agallocha* and *Rhizophora apiculata* are the richest source of phytochemicals (Vinoth *et al*., 2019).

Medicinal uses of mangroves:

Many mangrove species produce expensive drugs with high export potential. Extracts from mangrove have been used in folklore medicines and show inhibitory activity against human, animal and plant pathogens (Tables 2, 3).

3.7 *Tannin*:

Tannins and dyes are valuable non-timber forest products originating in mangrove ecosystems, which can provide significant revenue to local communities. Bark of many species of mangrove have high tannin content and is used in leather tanning operations and as decorative dyes (UNEP, 2014). Tannins were extracted from the bark of mangroves by adding the wood to a solution of lead acetate and concentrated sulphuric acid (Friess *et al*., 2019). According to Baba *et al*. (2016), tannin-polyphenols exuded from *A. marina* leaves inhibited the maturation of *Culex* mosquitoes.

Kusmana and Sukristijiono (2016) reported

Table 3: Traditional medicinal uses of mangroves (Kathiresan, 2012; Shadia, 2016)

Part of mangrove	Species of mangrove	Uses in Indigenous medicine
Bark	*Rhizophora* spp.	Astringent, anti-diarrhoea and antiemetic activities
Extracts from leaves, stems, barks and roots	Mangrove spp.	Treatment of viral diseases (AIDS), leprosy and tuberculosis.
		Antioxidant activity
Fruits	*Sonneratia* spp.	Preparation of beverage
Leaves	*Bruguiera* leaves	Reduce blood pressure
	Excoecaria agallocha	Treatment of leprosy and epilepsy
Roots and stems	*Derris trifoliata*	Narcotizing fishes
	Acanthus ilicifolius	Treatment of rheumatic disorders
Seeds	*Xylocarpus* spp.	Anti-diarrhoeal activity
	Avicennia spp.	Tonic effect
	Ceriops spp.	Hemostatic activity
Tannin	*Ecocoecaria agallocha*	Treatment of tonsilitis, pharyngeatis, haemmorjoids. slaik eruion, burns, diarrhoea and intestinal bleeding.
		Antidote for metallic, alkaloidal and sylycosidic poisons.
Tender leaves	*Acrostichum* spp.	Used as a vegetable

that high qualities of tannin is derived from mangrove species such as *Rhizophora*, *Ceriops* and *Bruguiera*. Tannin is used in the manufacture of leather, inks, plastics, boiler water, oil-well drilling, formaldehyde glues, rust preventives, insecticides and medicine. Sukardjo (2004) noted that dyes are extracted from the bark of *Xylocarpus granatum* and are used in dying fish nets, ropes and textile (batik), while extract from *Ceriops tagal* is used in colouring rice and local wine tuba. Though tannin from mangrove bark has traditionally been an important use of mangroves, in recent years synthetic tannin, to a large extent, has replaced this use (Hong, 2003; Giesen *et al*., 2006).

3.8 *Timber and construction*:

The mangrove wood with high content of tannin is used as timber for its durability (Kathiresan, 2012). In Sri Lanka, straight stems of *Rhizophora*, *Bruguiera* and *Ceriops* which are heavy hardwood with tannin-rich bark are used as material for homes, buildings, railroad ties and to construct the frames of the thatched roofs and windowpane frames (Baba *et al*., 2013). Mangrove timber is very dense, resistant to termites and rot with a corresponding ability to withstand exposure to saltwater. Mangrove timber is used for building poles, in boat-building and also for construction of docks, fences, and fish traps (UNEP, 2014).

Hard (durable) and heavy wood of *Rhizophora*, *Bruguiera*, *Ceriops*, *Xylocarpus*, *Sonneratia*, *Avicennia*, *Lumnitzera* and *Heritieralittoralis* are used for poles, piles, ship building, crafts, tool handles, railroad ties, furniture, and for other construction materials (Kusmana and Sukristijiono, 2016). Vinoth *et al*. (2019) noted that timber of mangroves has been used to build dwellings and lattice, furniture, studs for houses, rafters, joists, telegraph poles, fences, bridges, railway sleepers, poles for fish traps, paddles and rafts, canoes and boats. In Indonesia, mangrove woods are harvested to meet the needs for housing materials, household articles, paving blocks, tool handles and fishing gears (Kusmana and Sukristijiono, 2016).

4. *Regulating and Supporting services* (*Regulation*

of ecosystem processes, climate and maintenance of healthy coastal ecosystems):

4.1 *Climate regulation*:

Mangroves act as a significant global carbon store

sink and are important in carbon capture (carbon sequestration) (Maiti and Chowdhury, 2013). Donato *et al*. (2011) noted that mangroves are the largest average carbon stocks per unit area and the global average carbon stock of mangroves is around 1,000 tonnes of carbon per hectare, including soil carbon.

Mangroves have higher average carbon stocks per unit area in soil, ranging from about 83% to 99% of the carbon stored in mangroves. Mangrove soils emit relatively low levels of methane and represent highly effective, longer term carbon stores. Organic matter from leaf litter and other sources is trapped and eventually stored in the deep, waterlogged carbon-rich mangrove soil (UNEP, 2014).

4.2 *Coastal protection*:

Mangroves offer low-cost natural approaches to disaster risk reduction in the face of rising sea levels and changes in storm frequency and intensity. They play a potential role in coastal risk reduction associated with storms and tsunamis.

Tropical cyclones:

Tropical cyclones (hurricanes and typhoons) include large waves, storm surges and high winds which can cause loss of life and damage to property and infrastructure. Mangroves reduce risk from such cyclones by decreasing the action of waves and impacts of flooding as a result of storm surges. As waves travel through the mangroves, energy is dissipated by the mangrove tree roots, trunk and canopy (McIvor *et al*., 2012).

Storm surges:

Storm surges are flows of sea water onto the land, driven by high winds and low pressure and cause massive loss of life and destruction of property. Mangroves reduce storm surge levels by up to 50 cm per km width of mangroves (Zhang *et al*., 2012). IFRC (2011) recorded that along with mangroves, natural and built infrastructure can be combined to maximise the mitigation effect on storm surges.

Tsunamis:

Mangroves cannot completely stop a tsunami, but they can absorb some of the energy of the flowing water and reduce the force of the impact, saving lives and reducing damage to property (Laso *et al*., 2011). Mangrove trees also disrupt the huge flows of water as the wave recedes, and block property and people from being swept back out to sea. They provide adequate protection from a large tsunami, and other risk reduction measures (physical barriers, early warning systems, evacuation plans, refuge centres) in areas where tsunamis could occur (Gedan *et al*., 2011).

Spalding *et al*. (2014) documented that mangroves protect coasts by reducing the risk from natural hazards (storms, tsunamis and coastal erosion) by:

- Rapid reduction in wind and swell waves to lessen the wave damage
- Reduce the flooding impacts of storm surges occurring during storms
- Reduce flood extent in low lying areas
- Reduce tsunami heights and reduce loss of life and damage to property
- Dense roots of mangroves help to bind and build soils to reduce erosion.

According to Friess *et al*. (2019), mangrove forest can attenuate incoming hydrodynamic forcing under certain conditions due to friction caused by the complex above-ground root architecture and the mangrove surface. Mangrove forests provide a regulating ecosystem service through trapping and consolidating sediment, leading to erosion control and sediment accretion (Lovelock *et al*., 2015).

4.3 *Provision of nursery habitats*:

Christine (2005) noted that exposed prop roots

and pneumatophores of mangroves provide ample hiding places and plenty of food to fish and to juvenile fish with refuge from large predators. Commercially important species such as spiny lobster and reef fish (grunts and snappers) use mangroves as nurseries. The mangrove wetlands offer refuge and nursery grounds for juvenile fish, crabs, shrimps, and molluscs. Mangroves also provide support to off-shore fisheries by serving as a breeding ground (IUCN, 2006). Mangrove nurseries not only sustain offshore fisheries, but can also enhance the populations of fish species of adjacent ecosystems (UNEP, 2014).

4.4 *Soil stabilisation and erosion control*:

One of the important ecological function of mangroves is to serve as a windbreak and shore line stabilizer (IUCN, 2006). Mangroves help to stabilise shorelines and mitigate coastal erosion by reducing the height and energy of waves, minimising erosive forces acting on the sediment and preventing it from being carried away from the shore (Quartel *et al*., 2007; McIvor *et al*., 2012).

According to Karen and Vervaeke (2009), subsurface roots of mangroves bind the soil together and aerial roots change the water flows, helping to retain sediment within the mangrove and encourage sediment deposition. Mangroves help to reduce coastal erosion by slowing water currents and holding sediments in place. By retaining sediment, mangroves stabilise soil and build it up through the action of roots that grow into the newly sedimented material, helping to bind it in place (UNEP, 2014).

Lee *et al*. (2014) observed that mangrove encourage sediment deposition and consolidation through their root systems, slow down the water and encouraging sediment deposition. They acts as 'land builders' (building land from the production of organic matter from dead roots) and 'land stabilizers' (mangrove roots consolidate and accrete mineral sediment).

4.5 *Nutrient cycling and Water quality maintenance*:

Mangrove forests maintain surrounding water quality by filtering riverine and tidal waters of sediments, minerals, contaminants and nutrients. Mangrove has high tolerance for a wide range of salinities and contamination levels and perform an effective service in bio-filtration and waste processing. Mangroves are also important in nutrient uptake, fixation, trapping and turnover. Mangrove ecosystem play a critical role in cycling nutrients and maintaining water quality (Saenger, 2002).

Physical structure of mangroves alter the turbidity of ambient waters through sediment trapping. Mangroves slow the water flow allowing sands, clays, heavy metals, and other sediments to drop out of suspension in the water column. Mangroves cannot solve the problem of water pollution alone and their degradation and loss can exacerbate decline in water quality (UNEP, 2014).

5. *Recreational, Spiritual and Cultural services* (*Non-material benefits obtained from mangroves*):

Cultural ecosystem services refer to a range of tangible and non-tangible social benefits, including tourism, recreation, sense of place, and spiritual and aesthetic values (Friess *et al*., 2019).

5.1 *Recreational services*:

James *et al*. (2013) recorded that recreational values of mangroves are important for human well-being. Mangroves along with adjacent terrestrial forests, sea-grass beds and coral reefs, provide a variety of aesthetic and recreational experiences. Mangroves also provide opportunities for leisure, recreation and education. Mangroves are being opened up to residents and tourists alike for recreational fishing, bird watching and wildlife watching throughout the world (UNEP, 2014).

Spalding *et al*. (2010) observed that mangrove forest locations such as the Dongchaigang nature reserve in China, the boardwalk in Cairns in Australia, Laguna de Resting in Venezuela and boardwalk in the Galapagos Islands (Ecuador) attract around 60,000 visitors annually.

5.2 *Spiritual services*:

Mangroves are interlinked with spiritual beliefs and practices such as festivals, religious rites, taboos and the establishment of sacred areas. For example, according to the legends of the Asmat people from Irian Jaya (West Papua, Indonesia), the creator carved human-like figurines out of a mangrove roots which came to life when he played a drum out of a mangrove tree (UNEP, 2014).

As noted by Kathiresan and Bingham (2001), mangrove tree roots are still used to carve intricate ceremonial poles to commemorate specific individuals and ancestors and other items such as drums, shields and figures. In Kenya, shrines built in the mangrove forests are worshipped by the local people, who believe spirits of the shrine will bring death to those who cut the surrounding trees.

Strong spiritual links between mangrove forest and local communities in Fiji, with particular deities and legends associated with different components of the mangrove ecosystem (Friess *et al*., 2019). Mangrove forests play a spiritual role during burial ceremonies and in Australian aboriginal ceremonies, dead were buried in a grave and covered with mangrove saplings while in Papua New Guinea the dead were left exposed in the forest as a method of preservation (James *et al*., 2013).

5.3 *Cultural services*:

In some coastal communities, mangroves form an integral part of their cultural heritage and identity. The continued presence of mangroves maintains traditional fishing methods and traditional ecological knowledge including the uses and harvesting methods for specific plant and animal species. Birdlife and wildlife inhabiting mangroves are widely shared and culturally embedded to attain high intrinsic or existence value (UNEP, 2014).

5.4 *Scientific research and education*:

Mangrove ecosystems are a focus for ecological research, hydrographic studies and education. These living laboratories have contributed vastly to our knowledge about marine systems and connections between marine systems and freshwater systems, as well as linkages between ecosystem health and human well-being (UNEP, 2014).

5.5 *Aesthetic value*:

According to UNEP (2014), mangroves can also hold high aesthetic value. Birdlife and wildlife inhabiting mangroves further contribute to their aesthetic value. Mangroves may also provide opportunities for leisure and recreation. In the United Arab Emirates, people have a high affinity with mangroves and are valued for colouring a landscape.

5.6 *Ecotourism services*:

Mangrove lagoons are highly valued for ecotourism ventures. Kayaking and sailing tours take place in these areas, since they are calm and provide a safe area for both novice and expert boaters. Because of the huge diversity of marine organisms found in mangrove lagoons, snorkelers may be able to see species that they may not otherwise be able to find (Christine, 2005).

Kusmana and Sukristijiono (2016) recorded that mangrove usually forms a beautiful landscape and can be used for sightseeing purposes. Many modern life styles, look for mangroves, to conduct cultural activities, and tourism interests. The mangrove forest provides visitors with aesthetic enjoyment and fresh air as well as negative ion of oxygen in the forest areas.

Conclusion

In spite of their importance to people, mangroves are consistently undervalued and remain one of the most threatened ecosystems on the planet and are being lost at an alarming rate. Mangroves are considered as the wastelands with little use and of no value. This study recommends to allocate mangrove resources to improve human well-being. Due to rampant slaughtering of mangroves, successful restoration using sound scientific protocols is recommended to sustain this sensitive

ecosystem by community based approach. Remaining mangrove ecosystems must be protected and sustainably managed in order to secure their long-term future and the well-being of the coastal community.

Acknowledgements

Encouragement and support provided by Prin. Dr. Ganesh A. Thakur, Principal, Mahatma Phule Arts, Science and Commerce College, Panvel, Raigad, Navi Mumbai, India is gratefully acknowledged.

References

Adyel TM and Macreadie PI. (2021) World's largest mangrove forest becoming plastic cesspit. Front Mar Sci. 8: 766876.

Baba S, Chan H and Aksornkoae S. (2013) Useful products from mangrove and other coastal plants. ISME Mangrove Educational Book Series No. 3.

Baba S, Chan HT, Oshiro N, Maxwell GS, Inoue T and Chan EWC. (2016) Botany, uses, chemistry and bioactivities of mangrove plants IV: *Avicennia marina*. ISME/GLOMIS Electro J. 14(2): 5-10.

Baglo AA. (2005) Enjeux économiques des strategies de gestion durable des zones humides : cas de la zone située sur le cordon Abomey-Calavi-Degoue sur le littoral béninois. Laboratoire d'écologie appliquée, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, Cotonou, Bénin.

Bandaranyake WM. (1995) Survey of mangrove plants from Northern Australia for phytochemical constituents and UV-absorbing compounds. Curr Topics Phytochem (Life Science Advances) 14: 69-78.

Bidossessi SCMA, Ivan BK, Clement S, Mreille AT Paolo ADL and Marcel RBH. (2021) Utilization of plant species in mangrove swamp: ruminant herders' perception of treats and strategies for mangrove sustainable restoration in Benin (west-Africa). Res Square. doi.org/10.21203/rs.3.rs-256271/v1.

Christine OS. (2005) The importance of mangroves. Department of planning and natural resources. Division Fish and Wildlife. U.S.V.I. Fact Sheet #28. pp. 1-3.

Crow B and Carney J. (2013) Commercializing nature: Mangrove conservation and female oyster collectors in The Gambia. Antipode 45: 275-293.

Dahdouh-Guebas F. (2013) Les biens et services écosystémiques: l'exemple des mangroves. In: Vers une nouvelle synthèse écologique: de l'écologie scientifique au développement durable, (ed.) Meerts P., pp. 182–193.

Dahdouh-Guebas F, Mathenge C, Kairo JG and Koedam N. (2000) Utilization of mangrove wood products around Mida creek (Kenya) amongst subsistence and commercial users. Econ Bot. 54: 513-527.

Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M and Kanninen M. (2011). Mangroves among the most carbon-rich forests in the tropics. Nat Geosci. 4: 293-297.

FAO. (2012) Socio-economic assessment and economic valuation of Egypt's Mangroves. In: rehabilitation, Conservation and Sustainable Utilization of Mangroves in Egypt. www.fao.ora/ docrepboylae212e/ae212e06html.

Friess DA. (2016) Ecosystem services and disservices of mangrove forests: Insights from historical colonial observations. Forests 7(9): 183.

Friess DA, Rogers K, Lovelock CE, Krauss KW, Lee ST, Lucas R, Primavera J, Rajkaran A and Shi S. (2019) The state of the world's mangrove forests: Past, present and future. Annu Rev Environ Resour. 44(1): 89-115.

Gedan KB, Kirwan ML, Wolanski E, Barbier EB and Silliman BR. (2011) The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. Clim Change 106: 7-29.

Giesen W, Stephan W, Max Z and Liesbeth S. (2006) Mangrove Guidebook for Southeast Asia. RAP Publication 2006/07. ISBN: 974-7946-85-8, pp. 198.

Goldberg L, David L, Nathan T and Temilola F. (2020) Global declines in human-driven mangrove loss. Glob Change Biol. 26: 5844-5855.

Govindasamy C. (2011) What is the significance of mangrove forests: A note. Curr Botany 2(2): 50-55.

Govindasamy C and Kannan R. (2012) Pharmacognosy of mangrove plants in the system of Unani medicine. Asian Pacific J Trop Dis. 2: S38-S41.

Hamilton SE and Casey D. (2016) Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21). Glob Ecol Biogeogr. 25(6): 729e738.

Hong PN. (2003) Mangrove forests in Vietnam - present status and challenges. Presented at the International Symposium on Conservation and Wise Use of Mangroves in Southeast Asia, 6-8 October 2003, Brunei Darussalam, pp. 17,

IFRC. (2011) Breaking the waves. Impact analysis of

coastal afforestation for disaster risk reduction in Vietnam. Report by the International Federation of Red Cross and Red Crescent Societies.

IUCN. (2006) Conservation benefits of mangroves. The World Conservation Union. IUCN Policy Brief, October 2006: 1- 6.

James GK, Jimmy OA, Sylvester O, Saba E, Peter N and Joseph A. (2013) Social valuation of mangroves in the Niger Delta region of Nigeria. Int J Biodivers Sci Ecosyst Serv Manag. 9: 311-323.

John J, Nandhini AR, Padmanaban VC and Mika S. (2021) Microplastics in mangroves and coral reef ecosystems: a review. Environ Chem Letts. https://doi.org/10.1007/s10311-021-01326-4.

Kangkuso A, Andi S, Nasaruddin, YS and Sharma S. (2019) Mangrove fruit bioprospecting: Nutritional and antioxidant potential as a food source for coastal communities in the Rawa Aopa Watumohai National Park, Southeast Sulawesi, Indonesia. Int J Fruit Sci. 19(4): 423-436.

Kantharajan G, Pandey PK, Krishnan P, Bharti VS and Deepak SV. (2018) Plastics: A menace to the mangrove ecosystem of megacity Mumbai, India. ISME/GLOMIS Electro J. 16(1): 1-5.

Karen LM and William CV. (2009) Impacts of human disturbance on soil erosion potential and habitat stability of mangrove-dominated islands in the Pelican Cays and Twin Cays Ranges, Belize. Smithson Contrib Mar Sci. 38: 415-427.

Kathiresan K and Bingham BL. (2001) Biology of mangroves and mangrove ecosystems. Adv Mar Biol. 40: 81-251.

Kathiresan K. (2000). A review of studies on Pichavaram mangrove, southeast India. Hydrobiol. 430: 185-205.

Kathiresan K. (2012). Importance of mangrove ecosystem. Int J Mar Sci. 2(10): 70-89.

Khafaji AK, El-Hassan AM, Mandura AS, Al-Hachim GH and El-Nakkadi AMN. (1993) Phytochemical studies on mangrove and the possibility of using it as fodder. J King Abdul Aziz Univ Mar Sci. 4: 181-195.

Kusmana C and Sukristijiono S. (2016) Mangrove resource uses by local community in Indonesia. J Pengelolaan Sumberdaya Alam dan Lingkungan 6(2): 217-224.

Laso Bayas JC, Marohn C, Dercon G, Dewi S, Piepho HP, Joshi L, van Noordwijk M and Cadisch G. (2011) Influence of coastal vegetation on the 2004 tsunami wave impact in west Aceh. Proc Natl Acad Sci. 108: 18612–18617.

Lee SY, Primavera JH, Dahdouh-Guebas F, McKee K, Bosire JO, Cannicci S, Diele K, Fromard F, Koedam N and Marchand C. (2014) Ecological role and services of tropical mangrove ecosystems: A reassessment. Glob Ecol Biogeogr. 23: 726-743.

Li D, Zhao L, Guo Z, Yang X, Deng W, Zhong H and Zhou P. (2021) Marine debris in the Beilun Estuary mangrove forest: Monitoring, assessment and implications. Int J Environ Res Public Hlth. 18: 10826.

Lovelock CE, Cahoon DR, Friess DA, Guntenspergen GR, Krauss KW, Reef R, Rogers K, Saunders ML, Sidik F and Swales A. (2015) The vulnerability of Indo-Pacific mangrove forests to sea-level rise. Nature 526: 559-563.

Maiti SK and Abhiroop C. (2013) Effects of anthropogenic pollution on mangrove biodiversity: A review. J Environ Protec. 4: 1428-1434.

Martin C, Hanan A and Carlos MD. (2019) Mangrove forests as traps for marine litter. Environ Poll. 247: 499e508.

Maxwell GS and Lai C. (2012) *Avicennia marina* foliage as a salt enrichment nutrient for New Zealand dairy cattle. ISME/GLOMIS Electro J. 10(8): 22-24.

McIvor A, Moller I, Spencer T and Spalding MD. (2012) Reduction of wind and swell waves by mangroves. Natural Coastal Protection Series: Report 1. Cambridge Coastal Research Unit Working Paper 40. 27.

Naik MS, Supanekar SP and Pawar PR. (2021) Assessment of marine debris and plastic polymer types along the Panvel Creek, Navi Mumbai, West Coast of India. Intern J Zool Invest. 7(1): 278-293.

Patil PD and Chavan NS. (2013) A need of conservation of Bruguiera species as a famine food. Ann Food Sci Tech. 14: 294-297.

PERSGA. (2004) Status of Mangroves in the Red Sea and Gulf of Aden. PERSGA Technical Series, No. 11, Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden, Jeddah, Saudi Arabia.

Quartel S, Kroon A, Augustinus PG.EF, Santen PV and Tri NH. (2007) Wave attenuation in coastal mangroves in the Red River Delta, Vietnam. J Asian Earth Sci. 29: 576-584.

Rao AN. (1987) Mangrove ecosystems of Asia and Pacific. In: Mangroves of Asia and the Pacific: status and management, (ed.) Umali R.M. Technical Report of the UNDP/UNESCO Research and Training Pilot Programme of Mangrove ecosystems in Asia and the Pacific, Quezon city, Metro Manila, 1-48.

Rovai AS, Twilley RR, Castaneda-Moya E, Riul P, Cifuentes-Jara M, Manrow-Villalobos M, Horta PA, Simonassi JC, Fonseca AL and Pagliosa PR. (2018)

Controls on carbon storage in mangrove soils. Nat Clim Chang. 8: 534-538.

Saenger SC. (2002) Mangrove Ecology, Silviculture and Conservation. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-9962-7

Sahu SC, Suresh HS, Murthy IK and Ravindranath NH. (2015) Mangrove area assessment in India: Implications of loss of mangroves. J Earth Sci Clim Change 6: 280.

Sathe SS, Lavate RA and Sajjan MB. (2015) The role of organic constituents of *Avicennia* in animal nutrition. Biosci Discov. 6(2):145-151.

Satheeshkumar P, Manjusha U, Pillai NGK and Senthil Kumar D. (2012) Puducherry mangroves under sewage pollution threat need conservation. Curr Sci. 102(1): 13-14.

Satuhu S. (2004) Handling and processing of fruit. Jakarta, Indonesia: Penebar Swadaya.

Semarang (2013) Mangrove based food products processing. Dyah llminingtyas WH and Faculty of Fisheries and Marine Science, Diponegoro University, pp. 12.

Sen H. (2019) The Sundarbans: A disaster-prone eco-region. Berlin, Springer. doi: 10.1007/978-3-030-00680-8.

Shadia MAA, Foukia EM, Yomna AM and Nayera AMA. (2016) Medicinal importance of mangrove plants. doi:10.1007/978-3-319-25277-3_5.

Situmorang RO P and Sriyanti PB. (2015) Mangrove management as source of food alternative by the women fishermen group in Sei Nagalawan, North Sumatra, Indonesia. Int. Conf. of Indonesia Forestry Researchers III 3rd INAFOR 2015 Bogor, 21-22 October 2015. pp. 118-127.

Spalding M, Kainuma M and Collins L. (2010) World Atlas of Mangroves. A collaborative project of ITTO, ISME, FAO, UNEP-WCMC, UNESCO-MAB, UNU-INWEH and TNC. 319 (Earthscan, 2010).

Spalding M, Mclvor A, Tonneijck FH, Tol S and van Eijk P. (2014) Mangroves for Coastal Defence. Guidelines for coastal managers and policy makers. Published by Wetlands International and The Nature Conservancy, pp. 42.

Sukardjo S. (2004) Fisheries associated with mangrove eco-system in Indonesia: a view from a mangrove ecologist. Bio-tropia 23: 13-39.

Teka O, Hentschel US, Vogt J, Bahr HP, Hinz S and Sinsin B. (2012) Process analysis in the coastal zone of Benin through remote sensing and socio-economic surveys. Ocean Coastal Managem. 67: 87-100.

UNEP. (2010) Integrated Solutions to Biodiversity, Climate Change and Poverty. Policy Brief.

UNEP. (2014) The Importance of Mangroves to People: A Call to Action. van Bochove, J., Sullivan, E., Nakamura, T. (Eds). United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, pp. 128.

Untawale AG. (1985) Mangroves of India. Present status and multiple use practices. In: Mangroves of Asia and Pacific: status and usage. The final document of UNDP/ UNESCO Regional project, p.67.

van Bijsterveldt CEJ, Bregje KW, Sri Ramadhani, Olivier VR, Fleur EG, Rudhi P and Tjeerd JB. (2021) Does plastic waste kill mangroves? A field experiment to assess the impact of macro plastics on mangrove growth, stress response and survival. Sci Total Environ. 756: 143826.

Vannucci MC. (1989) The Mangroves and Us. IAAS Publishers, New Delhi, p. 293.

Vinoth R, Kumaravel S and Ranganathan R. (2019) Therapeutic and traditional uses of mangrove plants. J Drug Deliv Therapeu. 9(4-s): 849-854.

Williams MJ, Coles R and Primavera JH. (2007) A lesson from cyclone Larry: An untold story of the success of good coastal planning. Estuar Coast Shelf Sci. 71: 364-367.

Zhang K, Huiqing L, Yuepeng L, Hongzhou X, Jian S, Jamie R and Thomas JS. (2012) The role of mangroves in attenuating storm surges. Estuar. Coast. Shelf Sci. 102-103: 11–23.