VOLUME 10 ISSUE 1 2024

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. 10, No. 1, 775-782 (2024)

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

Deforestation of Mangrove Ecosystem and Livelihoods of the Coastal Communities: A Comprehensive Review

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Received: 2nd February, 2024; **Accepted:** 7th May, 2024; **Published online:** 14th May, 2024

https://doi.org/10.33745/ijzi.2024.v10i01.084

Abstract: Mangrove forests are intertidal ecosystems formed by a remarkable group of trees that have adapted to live in waterlogged, salty and often unstable conditions. Main driving force causing mangrove decline is the direct human impacts and is responsible for over 60% of mangrove loss. Primary causes include conversion to farmland, aquaculture and urbanization. Natural or indirect human causes include erosion, sea level rise, and storms, with climate change. Efforts to protect mangroves have risen globally and, currently, around 42% of all remaining mangroves exist in designated protected areas. This review narrates a systematic literature survey to identify the driving forces of mangrove decline, impact of deforestation on livelihoods of the coastal communities, and strategies to be adopted for conservation and restoration of mangroves for sustainable development. It is an urgent need to initiate ever-greater efforts to protect the remains of mangrove ecosystem, and to start programs of restoration. Alongside protection, there is an imperative need for restoration of mangrove ecosystem for sustainable development and better livelihood of coastal communities. This study suggests that, as mangroves are vital to the health of the planet, it is necessary to share information on existing restoration projects, thereby helping to support effective restoration world-wide. Also, a global commitment to conserve, protect and restore mangroves is needed to safeguard this unique ecosystem.

Keywords: Mangroves, Deforestation, Livelihood, Ecosystem services, Threats, Restoration

Citation: Santosh P. Supanekar and Yojana S. Muniv: Deforestation of mangrove ecosystem and livelihoods of the coastal communities: A comprehensive review. Intern. J. Zool. Invest. 10(1): 775-782, 2024.

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Introduction

Mangroves are woody plant communities living in areas between the sea and the land, and are flooded by tides for part of the time. They make up one of the world's unique and most productive ecosystems. Mangrove plants cope with changes in salinity by evolving both xeromorphic and

halophytic characteristics. They have leathery, wax-like leaves that reduce water loss from the plants and stomata that are positioned to reduce evaporation. Mangroves avoid heavy salt loads in their tissues by excreting it through specialised salt glands and also dilute salt by holding extra water in fleshy leaves (Miththapala, 2008).

Spalding and Marice (2021) reported that, mangroves are found between the latitudes of 32°N and 38°S of the globe and also in the mouths of estuaries and in intertidal areas. Approximately 1/4th of the world's tropical coastline comprise mangrove ecosystems which are estimated to extend along an area of between 167,000 and 181,000 km^2, in 112 countries. Forty per cent of mangroves occur in South and Southeast Asia regions and the single largest area of mangroves in the world lies in Bangladesh, in the Sunderbans, extending over 600,000 ha (Kathiresan and Bingham, 2001).

Nandan *et al*. (2021) stated that mangrove ecosystems are coastal wetlands comprised of woody vegetation found in intertidal marine and brackish environment. These forests support a wide range of marine and terrestrial fauna that perform important ecosystem functions. The tropical, subtropical, and warm temperate climate regions of the world contain intertidal mangrove forests with enriched biodiversity composed of different species of flora and fauna, upon which millions of people depend on (Bhowmik *et al*., 2022).

Based on structural and functional characteristics, mangrove forests have been classified into six community types such as: fringing mangroves (occurs in coastline inundated by daily tides), riverine mangroves (occurs at the edge of major rivers draining into the oceans), basin mangroves (found at the back of both fringing and riverine mangroves), overwash mangroves (occur as intertidal isolated stands on the seaward side), stunted mangroves (scrub forests in abnormal tidal reach), and hammock mangroves (formed over accumulated mangrove-derived peat) (UNEP *et al*., 2020).

Mangrove forest ecosystems currently cover 14.7 million hectares of the tropical shorelines of the world (Wilkie and Fortuna, 2003), which represents a decline from 19.8 million hectares in 1980 to 15.9 million hectares in 1990. These losses represent about 2% per year from 1980 to 1990 and 1% per year from 1990 to 2000. Therefore, achieving no-net-loss of mangroves worldwide would require the successful restoration of approximately 150,000 ha/year, unless all major losses of mangroves ceased (Lewis, 2009).

Mangroves consists of woody plants growing in tidal flats of tropical and subtropical areas, mainly composed of evergreen shrubs or trees and subject to cyclical tidal flooding. The mangrove ecosystem is an organic integrated system composed of producers (including true mangrove species, mangrove associates, associated plants, benthic algae and phytoplankton), consumers (including fishes, benthos, zooplankton, birds, insects and mammals), decomposers (microorganisms), and inorganic environment (Wenqing *et al*., 2019).

Mangroves is a life-saving coastal ecosystem that scaling up protection and restoration for achieving the sustainable development goals (BMZ, WWF and IUCN., 2010). Mangrove ecosystems provide numerous ecological functions and services to both marine environments and to people. Over two thirds of coastal population inhabiting in East and Southeast Asia whose food, water and livelihoods are dependent on mangrove forests (Verge, 2017). With their rich biodiversity, mangrove systems support coastal residents' livelihoods and also serve as a buffer to protect shorelines from extreme climate disasters, including tropical storms, typhoons and tsunamis (Jiaman, 2019).

Almost half of the global population lives within a distance of 150 km to the coast. The majority of urban centres' concentrate at coastal locations due to trade traffic, fishery, recreation,

and tourism; which leave behind their environmental footprints. In consequence, massive utilization pressure bears down on coastal ecosystems, which are easy to exploit and can be competitors in terms of land use as in the case of mangroves. This led to a continuous overexploitation, degradation and destruction of the world's mangrove forests over the past decades (BMZ, WWF and IUCN., 2010).

Pranoto *et al*. (2019) revealed that, the mangrove ecosystem is complex, dynamic, unstable, and are easily damaged and difficult to recover. Coastal degradation can be observed as destruction of mangrove area. The impact of mangrove destruction is evidenced by a significantly eroded area and lessened biodiversity. The mangroves have been chopped down, for timber or firewood and the mangrove area was converted into a riparian area, or developed into an office area or residential population. Hence, the mangrove ecosystems are damaged mainly by natural disasters and anthropogenic activities (Rahmadi *et al*., 2023).

Bimrah *et al*. (2022) stated that, mangroves are linked to adjacent ecosystems (seagrass, coral reefs, estuaries, etc.) through physical, biochemical, and biological interactions. They are important nursery grounds and breeding sites for birds, fish, crustaceans, shellfish, reptiles and mammals; a renewable source of wood; accumulation sites for sediment, contaminants, carbon and nutrients; and offer protection against coastal erosion (Primavera *et al*., 2000). Calm hydrodynamic conditions of mangrove ecosystem encourage the deposition of fine sediments, to enhance important ecological functions such as fisheries provision and biodiversity (MoEF, 2022).

Mangroves have been heavily used traditionally for food, timber, fuel and medicine. Over the past 50 years, approximately one-third of the world's mangrove forests have been lost due to density of human population (Barbier, 2006). Major reasons for destruction are urban development, aquaculture, mining and overexploitation for timber, fish, crustaceans and shellfish. Unrestricted clear felling, aquaculture, overexploitation of fisheries along with alteration of hydrology, pollution and global warming will be the greatest threats to mangrove ecosystem (Alongi, 2002).

Hutchison and Ermgassen (2014) noted that, mangroves are widely recognized for their role in enhancing both small scale and commercial fisheries, they are rapidly disappearing. A fuller understanding of this ecosystem service and its value in both social and economic terms will help enhance the sustainable management of both mangroves and fisheries. Mangroves with greater physical complexity both in terms of patterns of channels, pools and lagoons, as well as the structure of roots which are important areas for shelter and for growth of some bivalves will enhance fisheries to a greater extent.

Mitra and Biswas (2021) revealed that livelihood of Sundarban people basically centres around the mangrove forests and their ecosystem services. The mangrove ecosystems remain indispensable in the lives of the people of Sundarbans, for ages. The existing livelihood as observed in Indian Sundarbans can be broadly divided into four major heads such as—agriculture, fishing and prawn seed collection; wood collection; handicrafts and tourism; and honey, wax and other non-timber forest product collection (Kalor *et al*., 2019).

However, there is no recent information available on drivers for deforestation of mangrove ecosystem and its impact on livelihoods of the coastal communities. The aim of this review was, thus, to collect relevant and recent information dealing with mangrove forests. Furthermore, the study also presents recent approaches on classification of ecosystem services, driving forces of mangrove decline, impact of deforestation on livelihoods of the coastal communities, strategies to be adopted for conservation and restoration of mangroves for sustainable development.

This article reviews the mangrove ecosystem with respect to current status, ecosystem services,

Table 1: Traditional mangrove forests goods and services (Source: Hamilton and Collins, 2013)

S. No.	Goods and Services	Description
1	Direct Food	Alcohol (Nipa), Apiculture for honey, Clam, Cockles, Crab, Molluscs, Plants (feed and fodder), Pollinating bats, Pollinating bees, Salt, Sugar (Nipa), Traditional aquaculture , Vinegar, Wild fish, Wild shrimp.
2	Mitigation	Flood control, Shoreline stabilization, Wind protection, Wastewater treatment, Carbon sequestration and mitigation, Ground water management, Pollutant treatment, (aquaculture runoff), Ocean protection.
3	Other	Tourism, Recreation, Medicinal products, Animal feed, Habitat.
4	Wood Products	Timber, Charcoal, Firewood, Boats, Stakes and poles, Home construction, Thatch, Tannin, Pulp, Bark.

drivers for deforestation, impact of deforestation on livelihoods of the coastal communities, and strategies to be adopted for restoration of mangroves for sustainable development. Review method adopted was based on the scientific literature survey from databases such as Scopus, Medline, EMBASE, Web of Science and Science Direct. The keywords used for reviewing the literature were the ones that refer to the issues concerning the mangrove ecosystem. For literature search, keyword "mangrove ecosystem" is combined with: current status, ecosystem services, drivers for deforestation, impact of deforestation on livelihoods of the coastal communities, and strategies to be adopted for restoration.

Ecosystem Services of Mangroves Forests: *Definition and Classification*:

Ecosystem services are the 'Nature's contributions to people' and can be defined as the welfare contributions and benefits people derive from ecosystems (Getzner and Islam., 2020). Ecosystem services are the benefits that humans derive directly or indirectly from ecosystem functions. Mangrove has many important ecosystem services and values (Sofian *et al.*, 2019; M4CR, 2020).

Hamilton and Collins (2013) reported that, traditional mangrove forests goods and services were of four types such as-- direct food, wood products, mitigation, and other (Table 1).

CICES (2017) stated that, the ecosystem services have been classified into four different categories such as-- provisioning, supporting/maintaining, regulating, and cultural (Table 2).

Driving forces of mangrove decline:

There are many driving forces responsible for decline of mangrove ecosystem such as-- man-made hazards (urbanization, agriculture, aquaculture, sewage and industrial effluent, oil pollution, cutting of mangroves, reduction of ecosystem health, overfishing, sand and iron ore mining, etc.) and natural hazards (flooding, grazing, poor natural regeneration, biofouling, cyclones, effect of climate change, effect of change in carbon dioxide, etc.) (Table 3) (Alongi, 2002).

Miththapala (2008) noted that rate of loss of mangroves have been the highest in the last ten years. Less than half the original extent of mangroves remain in the world today and half of the remaining habitats are degraded. Globally, the rate of mangrove deforestation is between 2-8% per year. As a result, mangroves are among the world's rarest and most threatened ecosystems (Sukardjo, 2004).

Impact of mangrove deforestation on Livelihoods of the Coastal Communities:

Barbier (2006) reported that, in Thailand, deforestation of mangroves have directly affected many coastal communities since households

Table 2: Ecosystem services provided by the mangrove ecosystem (Source: Sofian *et al*., 2019)

S. No.	Category	Indicator	Description
1	Provisioning	Aquaculture	Cultivation of brackish fisheries
		Energy source	Firewood for daily use
		Feedstock	Raw material
		Fishery	Fisheries: Source of food
		Honey	Sweet fluid collected bees
		Medicines	Traditional medicines
		Tannin	Phenolic substances for tannery
		Timber	Firewood, charcoal production, boat building, home construction, natural dyes manufacture, roof thatching, sewage treatment
2	Supporting/ Maintaining	Fish nursery	Breeding and nursery habitats for fish species
		Key habitat	Habitat to coastal seafood (species of fish, crabs, shrimps, bivalves, and gastropods)
3	Regulation	Carbon sink	Absorbing carbon dioxide
		Climate regulator	Play an important role on climate change
		Coastal protection	Protecting the coast from the onslaught of waves, winds and floods
		Environmental risk indicator	Mangrove as risk indicator
		Protection from sedimentation	Stabilization of land by restraining sediment
		Protection from sea water intrusion	Mangrove can protect from intrusion
		Protection from coast and soil erosion	Reduction of coast and soil erosion
		Reducing emission	Presence of mangrove reduces emissions
		Water bioremediation	Maintaining water quality
4	Cultural	Aesthetic value	The value of appreciation of the beauty of nature
		Ecotourism and recreation	Providing unique and aesthetic values. Suitable habitat for flora and fauna.
		Spiritual appreciation	Appreciation related to belief

depend directly on mangrove forests for fish and wood collection and/or benefit indirectly from the mangroves' support to coastal fisheries. Mangrove loss therefore affects the decision of households to look for outside employment. In Central Vietnam, rapid changes in local land-use systems, ownership, management practices of mangrove resources, and institutional arrangements in response to *doi moi*, have weakened the livelihoods of many shrimp farmers in the community (Le *et al*., 2008).

Melati (2013) stated that in Indonesia, conversion of mangroves to brackish water aquaculture ponds has severely decreased the ecological health of near-shore coastal systems and resultantly the livelihoods of coastal communities. Of these affected coastal communities, rural, poor populations are most negatively affected by loss of mangroves and privatization of coastal lands, with women bearing the largest burden of all.

Hutchison *et al*. (2014) reported that, mangroves close to populations are likely to be under greater threat, may be degraded or polluted, and hence less productive for fisheries potential; thereby affecting the livelihood of coastal population (Seary, 2019). According to MoEF (2022), healthy mangrove ecosystems harbour healthy fisheries resources and degradation of it will severely impact coastal resources and thereby

Table 3: Drivers for deforestation of mangrove ecosystem

S. No.	Drivers for deforestation	Description
1	Overexploitation of mangrove products	• Over-exploitation for fuelwood, timber, charcoal, tannins, shrimp and other aquaculture, unsustainable fishing practices, overharvesting. • Over-visitation; user conflicts with traditional fishing practices (i.e, damage to by motor boats) • Irresponsible trash disposal
2	Habitat destruction	• Shrimp farming and aquaculture. • Coastal development and land reclamation.
3	Habitat degradation	• Diversion of inland freshwater • Inland freshwater extraction
4	Pollution	• Inland farming. • Housing and development • Chemical and sewage pollution,
5	Invasive Alien Species	• Threaten native species. • Pose threat to the provisioning services. • E.g. Common cordgrass (Spartina anglica)
6	Climate Change	• Affect the provisioning, supporting and regulatory services of mangroves. • Changes in precipitation will retard growth, productivity and seedling survival in mangroves. • Decreased precipitation and increased salinity change species composition. • Increased natural disasters will increase physical damage to mangroves. • Sea level rise will result in the loss of land occupied by mangroves. • Changing wave climates increase coastal erosion and damage mangrove habitats. • Salt water intrusion will alter the salinity regime in mangroves, changing the species composition.

the livelihood for coastal communities.

Strategies to be adopted for Conservation of Mangrove Ecosystem:

Miththapala (2008) documented that strategies adopted for successful conservation of mangrove ecosystem include:

- Setting aside protected areas: To set aside protected areas where human use is restricted to varying degrees.
- Prevention of habitat destruction/ degradation through legislation.
- Creating awareness: To create awareness among the public that 'wetlands are not wastelands'. Celebration of 'World Wetlands day' on February 2nd of each year.
- Mangrove valuation: Studies on Indirect values of mangroves. Valuation studies of mangroves to highlight their varied importance to human well-being.

Strategies to be adopted for Restoration of Mangrove Ecosystem:

Wenqing *et al*. (2019) and Howard *et al*. (2023) stated that ecological restoration of mangroves is the process of re-establishing self-regulating and self-organizing ecosystems for orderly evolution by lifting human interference to reduce load pressure, or the process of assisting the gradual recovery or virtuous-cycle development of damaged ecosystems with artificial means as a supplement to self-recovery (Teutli-Hernandez *et al*., 2020).

According to Lewis (2009) and Ketelaars *et al*. (2013), successful mangrove forest restoration requires careful analyses of a number of factors in advance of attempting actual restoration. Greater

success at ecological mangrove restoration could be achieved with a four-step approach that includes:

- General site selection for restoration sites that includes examination of multiple coastal basins that contain mangroves.
- Specific site selection that looks at the history of changes in areal cover of mangroves and changes in hydrology at specific potential restoration sites, and targets hydrologic restoration of these sites.
- Establishing quantitative and measurable success criteria and use uniform criteria between study sites.
- Monitoring and reporting of progress toward achieving these success criteria, including reporting on lessons learned from both successes and failures.

Conclusion

Mangroves are vital to the health of the planet. Though rates of mangrove loss and degradation around the world have slowed in recent years, yet many areas still face significant threats from coastal development, clearing for aquaculture and agriculture, pollution and over-exploitation. Natural changes, compounded by climate change, are also driving losses. The loss of mangrove habitats means a steep decline in the ecosystem services they provide, from fisheries and water quality to carbon sequestration and coastal protection. This threatens coastal communities, jobs and food security. Protecting all remaining mangrove cover is just one albeit critical part of the solution. It is necessary to enhance recovery, allowing natural regeneration and plantation of mangrove seedlings to restore the lost cover, and to protect all remaining mangroves. Also, to share experiences related to mangrove restoration, aquaculture extension and improved management, and approaches to sustainable livelihood alternatives in degraded areas is recommended.

Acknowledgements

Supanekar gratefully acknowledges the encouragement and support provided by Dr. Ganesh A. Thakur, Principal, Mahatma Phule Arts, Science and Commerce College, Panvel, Raigad, Navi Mumbai,India. Muniv is thankful to The Principal, Changu Kana Thakur Arts, Commerce and Science College, New Panvel, Navi Mumbai, Maharashtra, India for guidance and healthy cooperation.

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