Anthropogenic threats and conservation of mangrove biodiversity

A fisherman of southern Thailand once said "If there are no mangrove forests, then the sea will have no meaning. It is like having a tree with no roots, for the mangroves are the roots of the sea." Mangroves are the most significant and threatened terrestrial plants located at the interface of where land and water meet (McDowell, 2017). Mangroves are woody shrubs that consists of 80 different species such as *Avicenniace* and *Rhizophoracea* which are most commonly known as black and red mangrove respectively. They are mostly abundant at muddy shores such as lagoons and estuaries (McMeans, 2020). These muddy sediment habitats are home to numerous species of invertebrates, phytoplankton, zooplankton and fish. The main question to be addressed in this paper will be the threats of anthropogenic activities to the mangrove species in different parts of the world and how it is affecting the associated species that call mangroves home. Furthermore, what conservational measures are being implemented to preserve mangroves?

Mangroves have a high tolerance to high salinity, strong tides and extreme temperatures. Due to living in such extreme environments, mangroves have developed different mechanisms to gain salt and water despite having strong osmotic potentials. They tend to get rid of excess salt in three different ways as taking up excess salt can be harmful and deadly to the mangrove ecosystem. They exclude salt by their roots or excrete excess salt via leaves and bark. Furthermore, mangroves are a victim of water loss due to a reduced osmotic difference between roots and loose salt water sediment. Mangroves are surrounded by loose waterlogged sediment which is very low in oxygen. Oxygen is a basic requirement for a plant to grow and function. Without oxygen, any plant will wilt and die. Since mangroves live in these anoxic conditions, they have developed three morphological adaptations to obtain oxygen for their roots via aerial roots, root knees and pneumatophores or tubes. Figure 1 represents the three morphological adaptations of mangroves that enable its submerged roots to acquire oxygen to survive. These root structures consists of pores known as lenticles which continuously get access of oxygen from the atmosphere (McMeans, 2020).

One of the most productive and diverse wetland species are mangroves that provides its services to the surrounding terrestrial and marine environments in many ways. They are a buffer between terrestrial and marine environments. One of the major causes of global warming and climate change is the excess emission of carbon from the environment. A global increase of 36% of carbon emission has been observed from 1992 to 2008 and it is still on the rise. Mangroves play a definitive role by acting as an effective carbon storage system by removing the high amount of CO_2 levels in the atmosphere. This also helps prevent soil erosion and stabilizes the soil particles in mangrove forests (Maiti and Chowdhury, 2013). Mangroves forests are known to have high amounts of carbon in the tropics indicating high carbon assimilation and flux rate. A recent study has shown that a total of 122 million tonnes of carbon was released from mangrove forests in Malaysia, Myanmar and Indonesia due to deforestation (Davis, 2018). Different marine organisms also live in these mangrove forests and trees. The fully submerged roots surrounded by loose sediment tends to attract bacteria, fungi and invertebrates. Figure 2 is a visual representation of the strong roots of mangroves that provide shelter and nutrients for the

mentioned marine organisms. The upper portion of the tree like aerial roots, branches and leaves host invertebrates such as different crab species. Mangrove leaves are generally not edible due to a high amount of carbon compared to nitrogen. The Grapsid crab feeds on mangrove leaves as they have the ability to digest them. (McMeans, 2020). Deforestation and aquaculture is destroying mangrove habitats which is not only effecting mangroves but also the species that reside in these massive lands. The western red colobus and false water rat are two examples that are endangered due to the anthropogenic activities that are clearing mangrove forests (Johorey, 2017). Mangrove leaves and wood can also be used for purposes such as firewood, charcoal and timer. Different parts of the mangrove tree like roots and leaves can be utilized in the development of indigenous medicine. In India, mangrove forests are densely populated which as a result attract insects like honey bees. The large populations of honey bees are responsible for the great revenue of honey in India which increases the productivity of apiculture farms. Mangroves and honey bees have a mutualistic relationship. Therefore, the endangerment of mangroves would negatively impact the honey bee population. Different birds, bees, reptiles and amphibians also contribute to the mangrove forest biodiversity (Kathiresan, 2012).

Mangroves are very well adapted to deal with natural stressors like temperature, anoxia and salinity due to living at the interface of land and water. However, since they live and survive close to their tolerance levels, they can be extremely sensitive to anthropogenic pollution. Mangrove forests used to cover over 20,000 km^2 of tropical coastlines. In recent times, this number keeps on dropping 1-2% each year due to human disturbances and growing civilization. These anthropogenic activities include aquaculture, coastal development and over harvesting (Duke et al., 2018). Figure 4 shows devastating scenes of a mangrove habitat in Indonesia that fell victim of habitat destruction and aquaculture. About 25 countries of Asia have mangrove ecosystems with the highest biodiversity of more than 50 species of mangroves. These mangrove ecosystem are constantly affected by natural causes like severe storms and hurricanes. In addition to that, Asian mangroves are also being affected by anthropogenic disturbances like intensive logging, land conversion for crops and pollution. According to a study, 25% of mangrove loss has been observed since 1980 in all Asian countries (Maiti and Chowdhury, 2013). According to Figure 3, Indonesia and Australia have the largest mangrove areas of 19% and 10% respectively. Malaysia had about 575,000 hectare of mangrove forests but in recent times have decreased by 17% due to agriculture, urbanization and aquaculture. The decline of mangroves is a major issue in today's world where human population is increasing rapidly. Conservation biologist and ecologist need to intervene and come up with solutions to preserve the mangrove ecosystem or the repercussions of these horrid anthropogenic acts could lead the species to extinction.

The conservation and protection of mangrove forests is critical as coastal mangrove forests provide numerous ecosystem services to humans and surrounding terrestrial and marine ecosystems. In order to start preserving the mangrove species globally, multiple scientific parties around the globe must be committed in order to implement effective conservatory practices to restore the declining trend of mangrove species. Currently, more than 16% of the mangrove species worldwide are classified as critically endangered, endangered or vulnerable in the IUCN red list and none of the 70 mangrove species listed are classified as protected. 2 species were

noted as critically endangered which have the highest probability to go extinct. In the southeast parts of Asia, 80% of mangrove areas have been lost over the past 60 years due to anthropogenic threats like aquaculture, crop farming and coastal development (Polidoro et al., 2010). An effective way to conserve mangrove species would be to work with local communities and act on the policies and regulations imposed by the government. Global conservation policies tend to be costly and time consuming so it would not be an easy task. Despite the severity of the situation, the task to conserve mangrove species is critical for everyone. Ecosystem service economic valuation (ESEV) is a conservation policy developed and implemented in various countries. The goal of ESEV is to conserve marine ecosystems by providing information on the costs associated with marine (mangrove) species and habitat loss. Furthermore, it also provides valuable information on the benefits of conservation and reforestation of species and how the species is contributing to the economy and well-being of human beings. This has encouraged countries like India and Indonesia to follow this policy. A significant rise in mangrove forests has been observed in Gujarat, India since 1993. Due to these conserving efforts, a substantial increase in mangrove fish species was seen in Gujarat where mangroves are densely populated compared to other coastal regions in India. This is resulting in the economy of India to thrive mainly from fisheries (Romañach et al., 2018). Table 1 exhibits different mangrove rich regions of the globe that benefit the economic value of the listed countries. For example, mangroves in Srilanka provide protection to the surrounding habitats from storms and hurricanes. Mangroves in southern Thailand are known to protect coastlines and to store excess carbon from the atmosphere. Countries like Indonesia and Malaysia are adapting to environment friendly approaches to conserve mangroves. The WCB economy is heavily dependant on tourism and fisheries. These ecosystem services are dependent on mangrove forests and thus the people are uniting to finance for the long term conservation of mangrove species. Successful conservation and restoration of mangroves species will require commitment from the local communities and governments globally (Romañach et al., 2018). However, as human population is increasing, people are not really interested in nature conservation. This is due to being poorly educated regarding these critical matters. In Malaysia, the government is taking the initiatives to educate people regarding conservation strategies of these important coastal resources. These educative programs are also financially motivating people to contribute for the sustainability and reforestation of mangroves.

Mangroves provide critical ecosystem services to humans and the surrounding terrestrial and marine habitats. A decline of more than 50% of mangrove species has been observed in countries like India, Indonesia and Malaysia etc. The main cause of deforestation and decline in mangrove species is due to anthropogenic activities. In order to conserve these productive and ecofriendly species, effective actions are being adapted by local communities and governments all over the globe. Conservational biologists and ecologists of the global mangrove alliance (GMA) are confident and hopeful that by the year 2030, mangrove habitats should increase by 20%.

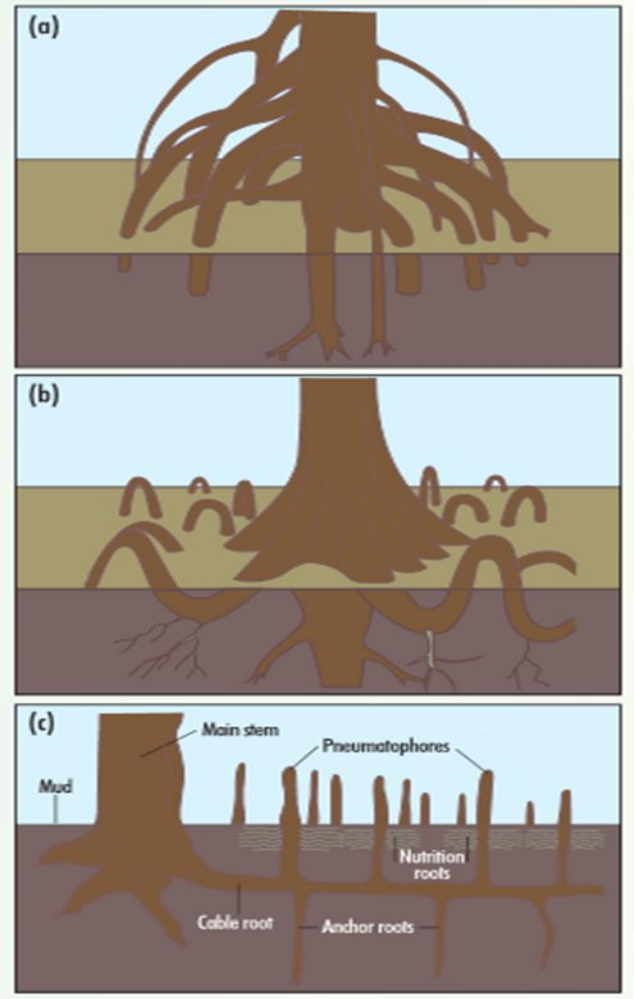

Figure 1: The three morphological adaptations of mangroves enabling its roots to acquire oxygen to survive (Marine Ecology, 2011).

Figure 2: Root structures of mangroves used for shelter for different species of fishes and invertebrates (Sen, 2018)

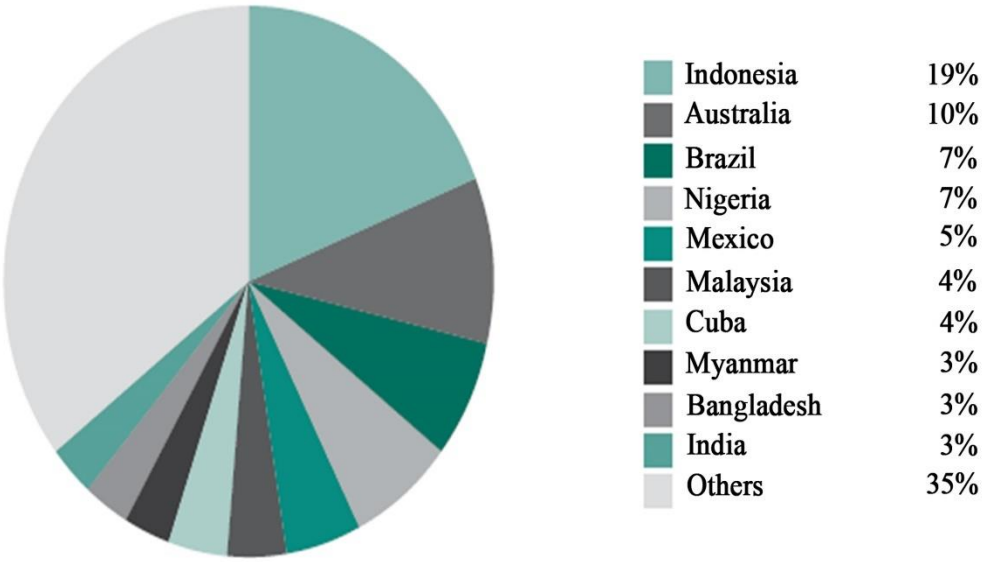

Figure 3: A representative of different species of mangrove area inhabiting different countries across the globe (Maiti and Chowdhury, 2013).

Figure 4: This image captures a previous mangrove habitat in Indonesia cleared for aquaculture (Davis, 2018).

Country	Item of value	Cost (USD/ha/year)
Indonesia	traditional use	3 000 (half of income among the poorest households)
Thailand	traditional use	230~1 200
Southern parts of Thailand	traditional use	1 500 per household (a quarter of per capita GDP)
In southern Thailand	coastline protection and stabilization services	3 000
	carbon sequestration	100
Koh Kong Province in Cambodia	local level uses and indirect values	500~1 600
Rekawa, Sri Lanka	Coastal protection from storm and fisheries values	1 000
Sri Lanka	storm protection	8 000 00
Irian Jaya	erosion control service	600 per household per year
South of Vietnam	protection against extreme weather events	5 000 00
South east Thailand	Ecosystem function	10 000
India (North Malabar)	Total monetary value	10 960
Global mangroves	forestry and fisheries benefits	500~2 500
	Disturbance regulation	1 839
	Waste treatment	6 696
	Habitat/refugee	169
	Food production	466
	Raw materials	162
	Recreation	658
	Total benefits	3 294
	Total economic value	9 990

Table 1: List of countries/regions and the respective economic value of mangroves for each geographical region (Kathiresan, 2012).

References:

1. Davis, M. E. 2018, May 3. New study finds mangroves may store way more carbon than we thought. https://news.mongabay.com/2018/05/new-study-finds-mangroves-may-store-way-more-carbon-than-we-thought/.
2. Duke, N. C., J.-O. Meynecke, S. Dittmann, A. M. Ellison, K. Anger, U. Berger, S. Cannicci, K. Diele, K. C. Ewel, C. D. Field, N. Koedam, S. Y. Lee, C. Marchand, I. Nordhaus, and F. Dahdouh-Guebas. 2007. A World Without Mangroves? Science 317.
3. Kathiresan, K. 2012. Importance of Mangrove Ecosystem. International Journal of Marine Science.
4. Maiti, S. K., and A. Chowdhury. 2013. Effects of Anthropogenic Pollution on Mangrove Biodiversity: A Review. Journal of Environmental Protection 04:1428–1434.
5. McDowell, E. (2017). Mangrove Matters. https://www.vergemagazine.com/work-abroad/blogs/2018-mangrove-matters-internship-at-mangrove-action-project.html.
6. McMeans, B. (2020). Mangroves Forests and Seagrass Meadows [PowerPoint slides].
7. Polidoro, B. A., K. E. Carpenter, L. Collins, N. C. Duke, A. M. Ellison, J. C. Ellison, E. J. Farnsworth, E. S. Fernando, K. Kathiresan, N. E. Koedam, S. R. Livingstone, T. Miyagi, G. E. Moore, V. N. Nam, J. E. Ong, J. H. Primavera, S. G. Salmo, J. C. Sanciangco, S. Sukardjo, Y. Wang, and J. W. H. Yong. 2010. The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern. PLoS ONE 5.
8. Romañach, S. S., D. L. Deangelis, H. L. Koh, Y. Li, S. Y. Teh, R. S. R. Barizan, and L. Zhai. 2018. Conservation and restoration of mangroves: Global status, perspectives, and prognosis. Ocean & Coastal Management 154:72–82.
9. Sen, S. 2018, February 2. Mangroves –A Muddy Affair! https://www.earthwiseaware.org/a-muddy-affair-mangroves/.
10. Johorey, J. 2017, January 11. Endangered Animals of the Mangrove Forests. Animalwised.com. https://www.animalwised.com/endangered-animals-of-the-mangrove-forests-1314.html#anchor_6.
11. Marine Ecology: Processes, Systems and Impacts. 2011. Kaiser, M.J., Attrill, M.J., Jennings, S., Thomas, D.N., Barnes, D.K.A., Brierley, A.S., Greert Hinddink, J., Kaartokallio, H., Polunin, N.V.C., Raffaelli, D.G. (editors). Oxford University Press, Oxford.