Figure 3. Mangrove root structure. Retrieved from Marcus (2018).

Mangrove Deforestation

Figure 4. Aquaculture ponds carved out of a mangrove forest. Retrieved from Valiela, Bowen, & York (2001).

When I was in the 2nd grade we did a science experiment, we were all given styrofoam cups with soil, we placed a seed in the dirt, added some water and left it underneath the classroom window. After a few weeks, seedlings began to sprout and eventually a flower bloomed. These were the fundamentals we were taught when it came to plants, but there is so much more. Plants can be picky when it comes to where they want to grow, dandelions seem like they can grow everywhere, but I can never find a four-leaf clover. This also occurs in tree species, pine trees are abundant, but species like mangroves only grow in areas no other tree could. The value trees have on all life on earth is incredible, but how can we quantify the destructive force deforestation continues to have, especially on local communities? Mangrove forests have declined substantially in the last 50 years and the repercussions could be extinction if intervention is not imminent. Let's dive into mangroves and explore the impacts these trees have in the areas they inhabit.

The collection of trees and shrubs that line intertidal coastal areas are known as mangrove forests (National Oceanic and Atmospheric Administration [NOAA], 2018). There are approximately 80 different species of mangrove trees; due to the availability and abundance of light the trees only grow in tropical and subtropical climates (NOAA, 2018). Table 1 exhibits the distribution of mangrove forests globally, with predominant coverage in Indonesia (Luther & Greenberg, 2009).

Mangrove forests comprise the only tree species to inhabit coastal intertidal areas. These regions consist of soil saturated in water and salt, and poor oxygen concentrations, conditions too harsh for most trees to survive (McMeans, 2019). Mangroves, however, have distinct adaptations allowing them to thrive along coastal areas and most importantly, saltwater conditions. Figure 1 shows the morphological adaptations mangrove trees have developed to obtain necessary oxygen (McMeans, 2019). The root structures, in all three examples, exit the sediment to allow access to air (McMeans, 2019). Figure 2 displays an example of how mangroves account for the excess salt in their environment. In addition to leaves, mangroves can excrete salt through their roots and bark (McMeans, 2019). This adaptation is necessary because, in a salt saturated environment, mangroves constantly battle water loss due to osmosis (McMeans, 2019).

Mangrove forests are productive ecosystems with numerous benefits to the surrounding terrestrial and marine environments, sustaining human activities as well. Mangroves serve as a buffer between the marine and terrestrial environments. The trees protect the coastal areas from erosion, floods and wave action, along with reducing effects from cyclones, tsunamis and floods (Kathiresan, 2012). One study examined the damages after of the 2004 Sumatra tsunami, which was generated after a 9.3 magnitude earthquake (Kathiresan &Rajendran, 2005). Table 2 depicts the number of deaths and financial losses in 18 habitats, all with different variations of coastal vegetation (Kathiresan & Rajendran, 2005). Examination of table 2 illustrates that areas protected behind mangrove forests had the lowest deaths and financial losses, in comparison to areas with other vegetation. Mangroves are also extremely carbon – rich, utilizing carbon dioxide for photosynthesis and providing our oceans with more than 10% of organic carbon (Kathiresan, 2012). Mangrove forests can hold up to 25.5 million tonnes of carbon per year and are exceptional at recycling other nutrients, as well, such as nitrogen and sulphur (Kathiresan, 2012). In addition to recycling, mangroves can actually trap pollutants. In Indonesia, specific species of mangroves have been planted to control salinity and pH in aquaculture ponds, as well as, absorbing heavy metal contamination (Kathiresan, 2012). Mangrove forests have also developed to be an important habitat for marine species. The root structures displayed in Figure 3 provide shelter for nurseries, as well as, breeding and feeding of many fish species (Kathiresan, 2012). One study found 69 species, marine and terrestrial, that are dependent on mangrove forests and are considered mangrove endemic species (Luther & Greenberg, 2009). The economy thrives in regions were mangrove forests are densely populated, not only from fisheries, but forestry and apiculture as well. Mangrove wood and leaves can be utilized for firewood, timber, charcoal and indigenous medicine (Kathiresan, 2012). Whereas mangrove forests in particular areas, such as India, attract large populations of bees, leading to productive apiculture farms (Kathiresan, 2012).

Anthropogenic influences are a great threat to mangrove species. Activities such as clearing, overharvesting, overfishing, pollution, climate change and changes in local waterways have all contributed to the decline in mangroves (Valiela, Bowen, & York, 2001). The most significant loss in mangrove forests have occurred in Southeast Asian countries, with almost

50% loss in population due to deforestation (Valiela, Bowen, & York, 2001). These countries have taken advantage of coastal intertidal areas for development in aquaculture, such as shrimp farms (Valiela, Bowen, & York, 2001). The IUCN Red List of Endangered Species, have identified eleven species of mangroves that qualify for categories of threat, due to the continued clearing of mangrove forests (Polidoro et al., 2010). Of those eleven species, six are classified as Vulnerable, three as Endangered and two as Critically Endangered, the highest probability of extinction by the IUCN (Polidoro et al., 2010). The Critically Endangered category means there will be an 80% population decline over a three-generation time frame (Polidoro et al., 2010).

Conservation efforts are underway globally in an effort to protect the current mangrove populations, as well as, seed new mangrove forests. A global conservation effort would be to classify all mangrove species as protected and their coastal ecosystems protected habitats. This may sound easy enough, but global conservation policies are time consuming and costly. Even though 2 species of mangroves are listed as critically endangered, they and their habitats have yet to be classified as protected worldwide (Polidoro et al., 2010). A more efficient approach to mangrove conservation is to work with local communities. The World Wildlife Fund (WWF) has partnered with several countries with significant mangrove loss, to address individual threats. In Pakistan the WWF is focusing on 21 000 acres of mangrove rehabilitation and the reforestation of 2.5 million mangrove trees, with aid from the Pakistan Navy (Marcus, 2018). In Malaysia resources are allocated to education and protection strategies. In 2016, Tun Mustapha, a marine park conservation area was established to halt the loss of 1.5 million acres of mangroves (Marcus, 2018). Tun Mustapha encompasses approximately 9000 km^2 of islands and surrounding ocean (Marcus, 2018). Moving to the world's second largest coastline, Indonesia, is home to 6 million acres of mangrove forests (Marcus, 2018). The leading cause of deforestation across these islands is aquaculture, see Figure 4. With aid from WWF, shrimp farmers are adopting more environmentally responsible approaches (Marcus, 2018). In 2017, PT. Mustika Minanusa Aurora (PT. MMA), became the first Indonesian based shrimp processing company to receive the Aquaculture Stewardship Council certification, ensuring "environmentally and socially responsible seafood" (Aquaculture Stewardship Council, 2019). This certification has allowed PT. MMA's business to grow and has influenced other aquaculture famers to improve their environmental impact (Marcus, 2018). The WWF's impact in Indonesia also includes mangrove rehabilitation and reforestation, this will promote tourism to the area and allow mangrove endemic species to thrive (Marcus, 2018).

Numerous consequences would arise if mangroves became extinct. These species are a crucial aspect of the intricate coastal ecosystem; without them, terrestrial destruction, human loss, economic decline and mangrove endemic species extinction would occur. Considerable conservation efforts have begun to combat the effects of deforestation. Maintained community involvement and education will ensure minimal anthropogenic effects to mangrove populations. With continued reforestation efforts, ecologists are hopeful that mangrove habitats will increase 20% by 2030 (Marcus, 2018).

Figures and Tables

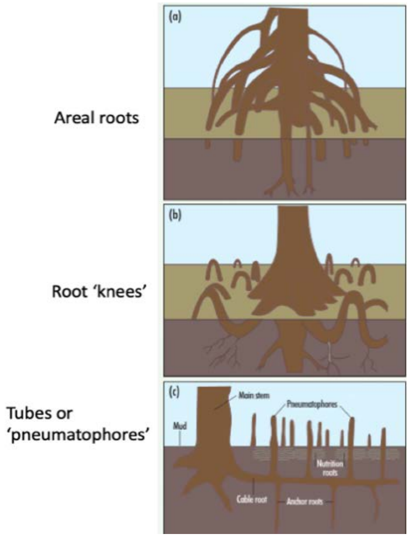

Figure 1. Mangroves morphological root adaptations. Retrieved from McMeans (2019).

Figure 2. Excess salt being excreted by mangrove tree leaf. Retrieved from Chen (2017).

Figure 3. Mangrove root structure. Retrieved from Marcus (2018).

Figure 4. Aquaculture ponds carved out of a mangrove forest. Retrieved from Valiela, Bowen, & York (2001).

West Africa	3	24,000
Indo–West Pacific		83,000
East Africa	4	8000
Indo-Malaysia	5	60,000
Australasia	6	15,000

Table 1. The global distribution of mangroves. Retrieved from Luther & Greenberg (2009).

Fishermen hamlet no.	Human inhabitation		Coastal vegetation		No. of deaths[a]					Per-capita loss of wealth (huts, gears & crafts (US $)
	Distance from sea (km)	Elevation from mean sea level (m)	Nature of habitat	Area (ha)	Male	Female	Child	Total	No./1000 individuals	
1	0.3	2.0	Sandy shore with mid shore dunes	0.5	2	4	1	7	16	511
2	0.3	3.0	Sandy shore with mid shore dunes	0.9	2	20	3	25	12	244
3	0.4	0.8	Low-lying sandy shore with embryonic dunes	0.1	23	57	13	93	72	333
4	0.4	2.0	Sandy with mid shore dunes	0.3	8	24	11	43	24	267
5	0.7	1.0	Sandy shore with hind dunes	0.4	9	17	2	28	19	244
6	0.7	3.3	Sandy shore with mid shore dunes	0.15	4	7	1	12	14	444
7	2.0	2.0	Muddy shore with dense mangroves	10	No death (0)				0	18
8	1.0	4.0	Elevated sandy shore with hind dunes	11.3	No death (0)				0	378
9	0.2	0.5	Low-lying sandy shore with embryonic dune	0.52	1	3	5	9	55	1000
10	0.4	4.0	Elevated steep sandy shore with mid shore dunes	15	1	1	0	2	4	289
11	0.1	0.8	Low-lying sandy shore	0.2	8	21	26	55	96	956
12	1.0	1.0	Mud-sandy shore with shrubby mangroves	2.0	2	2	1	5	11	222
13	0.1	0.5	Low-lying sandy shore	0.8	1	6	4	11	55	489
14	2.5	2	Muddy shore with dense mangroves	10	No death (0)				0	44
15	2.5	1	Muddy shore with dense mangroves	2	2	2	1	5	10	44
16	0.15	0.5	Low-lying sandy shore	0.28	0	1	3	4	80	267
17	0.15	0.5	Low-lying sandy shore	0.08	2	5	12	19	110	178
18	2.0	1.0	Muddy shore with dense mangroves	10	1	1	3	5	5	9

Table 2. Number of deaths and financial losses in 18 habitats with different coastal vegetation. Retrieved from Kathiresan & Rajendran (2005).

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