

The disappearance of mangrove ecosystems and how the problem is being approached

What is a mangrove? A mangrove is a halophytic shrub or tree species that is located in coastal intertidal locations and there are around 40 genera with around 70 species which has been recognized (Friess 2016). However, the term mangrove can also be used to refer to a mangrove ecosystem or forest. Mangroves can be found in tropical and subtropical coasts, ranging as far North up to Japan or Florida and as South as Australia and cover up to around 138 thousand square kilometers worldwide (Friess 2016). Unfortunately, Canada does not have any mangrove forests, which is why many Canadians may not be acquainted with this ecosystem or the problems that mangrove forests have been facing. Hopefully, this blog article can introduce the concept of mangrove forests to Canadians and raise awareness of some of the problems these forests are currently facing.

As mentioned before, mangroves grow at the intertidal zone. This means that mangroves are adapted to constantly changing and stressful conditions that are characteristic of the intertidal zones. Mangroves have reproductive adaptations that allow the offspring to establish in intertidal conditions. For example, the *Rhizophoraceae* produce seed that are able to germinate while still attached to the tree; this adaptation allows the seedlings to accumulate carbohydrates reserves which would allow for a fast development of roots when the seeds are released from the adult mangrove (Friess 2016). Mangroves are also adapted to withstand low oxygen levels in the soil and water inundation of roots by having root structures that extend above the ground which allow for gas exchange (Friess 2016). Finally, mangroves are halophytes which means they are able to tolerate saline and brackish water conditions. Some mangroves are able to live on salty conditions because they are able to excrete salts from glands or expel salts by shedding leaves (Friess 2016).

Why are mangroves important? Mangroves provide services for local populations. Mangroves can provide charcoal, timber, fish and shellfish to human populations. In addition, mangroves can also provide cultural and economical benefits to human populations, these include education, entertainment, and tourism (Friess 2016). Mangroves also provide protection to the coasts by attenuating wave action, coastal erosion and storm-surges (Bell & Lovelock 2013). Furthermore, they are also able to mitigate carbon dioxide emissions by anthropogenic factors by acting as carbon sinks. Mangroves can act as a sort of lateral filter of carbon by moving carbon to oceans, exchanging carbon dioxide with the atmosphere, and sequestering carbon from sediment (Alongi 2014; Rosentreter et al. 2018). Around more than half of the carbon that is moved by sediments is sequestered by coastal ecosystems, and around twenty percent of the carbon sequestered is exported to the ocean while the remaining is exchanged with the atmosphere in the form of carbon dioxide (Rosentreter et al. 2018). This make mangroves and any coastal ecosystems like estuaries or wetlands into the connection between terrestrial and marine carbon cycling.

For a long time, mangrove forests have been threatened and cleared because of urban development, aquaculture and agriculture expansion, landfill, and harvesting of charcoal and construction products (Duke et al. 2007; Friess 2016). Furthermore, pollution from nearby human communities has led to deterioration of mangrove forests' size and species richness (Duke et al. 2007). Aquaculture in the form of shrimp farms is one of the major factors driving the disappearance of mangroves (Duke et al. 2007; Friess 2016) and it is a complicated problem.

The development of ponds for the purpose of farming fish and shrimp has led to the loss of approximately thirty-eight percent of mangrove forests in the world (Polidoro et al. 2010). Shrimp farming is a complex problem because it has economic and ecological impacts. Economically, shrimp farms are important source of national income in tropical countries like Bangladesh (Ahmed et al. 2017), Vietnam (Ha et al. 2014) and Ecuador (Beitl 2016). During 2014-2015, Bangladesh ranked 6th worldwide in shrimp production by producing 2.06 million tons and shrimp farming is a multimillion-dollar industry contributing to the Bangladesh's economy (Ahmed et al. 2017). Ecologically, in the Ca Mau province of Vietnam, a boom in shrimp farms was correlated to an increase in the disappearance and pollution of mangrove ecosystems (Ha et al. 2014). In addition, in Ecuador, at least twenty-six percent of the original land coverage of mangroves has disappeared and been replaced by shrimp farms and urbanization since 1978 (Beitl 2016). Furthermore, a study done in Brazil has shown that despite the small coverage (0.007%) of aquaculture activities in Amazonian mangrove area, the impacts on water's pH, transparency, salinity, and temperature are greater than aquaculture activities establish in other areas such as coastal plateaus (Tenorio et al. 2015). The loss of mangroves can also affect human populations locally. For example, around 30% of the population (around 3000 families) in Ecuador's Muisne sector in the province of Esmeralda depend on food resources that could be acquired from mangrove forests, like fish, crustaceans and mollusks (Beitl 2016; FUNDECOL 2004). This means that the disappearance of mangroves could affect the livelihood of the populations that depend on it. Finally, blue carbon emission from mangrove deforestation has a huge impact in climate change (Ahmed et al. 2017). What is blue carbon? Blue carbon is the carbon utilized and stored by oceans and marine ecosystems (Ahmed et al. 2017). As previously mentioned, mangroves can act as a carbon sinks that could attenuate the effects of carbon dioxide emissions. According to the National Oceanic and Atmospheric Administration of the US Department of Commerce, mangroves and salt marshes can sequester carbon faster than forests and store them for thousands of years which would help in attenuating the climate change effects of carbon dioxide emissions. However, deforestation of mangroves due to shrimp farming release the blue carbon stored in these carbon sinks, and these blue carbon emissions contribute to climate change, and in turn also affect shrimp farming (Ahmed et al. 2017).

Conservation efforts have decreased the rates of deforestation of mangroves around the world. For example, in Southeast Asia, the rate of mangrove disappearance was around 1% annually during the decades of 1970s and 1980s; however, in recent years, the rates have been reduced to around 0.2% (Friess 2016). Furthermore, a lot of mangrove forests have also been designated as protected areas which protects them from being removed by expansion of aquaculture or agriculture (Friess 2016; Duke et al. 2007). In addition to designating protected areas, many laws have been made to punish the illegal deforestation of mangroves. For example, in Ecuador, laws have been established that hold illegal shrimp farmers accountable for harm done to coastal ecosystems (Beitl 2016). The law would make the farmer relinquish a great amount of the shrimp concessions and the farmer would also be responsible of reforesting a certain percent of the area depending on how much area the shrimp farm pond occupies illegally (Beitl 2016). Conservation is the first step to be taken to preserve mangroves, but a lot of mangroves previous land coverage have already been removed. Thus, restoration is also an important step to take to maintain the mangrove ecosystem. For example, FUNDECOL in Ecuador has taken the initiative of restoring around 13.28 hectares of mangrove forests which has been previously removed to make ponds for shrimp farming, but these ponds were

abandoned shortly. FUNDECOL along with other non-profit organizations planted approximately 27500 propagules of *Rhizophora mangle* and *Avicennia germinans* on different areas of the Muisne sector. These areas where propagules were planted showed survival rates of around 70% (FUNDECOL 2004). Since then, the area has been designated as a wildlife refuge and a protected area by the Ecuadorian government (FUNDECOL 2004). However, to rehabilitate mangroves in highly eroded areas, additional protection is needed to reduce wave energy and enhance seedling survival (Thornton & Johnstone 2015). Thornton & Johnstone (2015) tested two types of protection against waves to enhance seedling survival in two areas of the Kien Giang Province in Vietnam. In one area, they implemented a simple erected fence with a diameter of 20cm at the seaward edge to reduce wave energy, while they implemented a Kien Giang Biosphere Reserve Project (KGBRP) fence in another area. The KGBRP fence is more complicated and it involves two sets of erected poles and the space in-between the two poles is packed with brush and small branches. When compared with areas with simple fences, the rehabilitating areas with KGBRP fences had more factors that resembled the conditions of adjacent mangrove areas that hasn't been affected by erosion or anthropogenic factors. These factors included: tree and plant diversity, forest cover, tree density, mudskipper and crab density (Thornton & Johnstone 2015).

Restoration, rehabilitation and conservation efforts have made advances in protecting mangroves. However, these efforts also limit a country's profit from aquaculture or agriculture that could be established in those areas. A study by Tenorio et al. (2015) suggested that shrimp farms in mangroves areas of Brazil should be relocated to less ecological or economical impactful areas such as a coastal plateau. They found that shrimp farms in mangroves produced shrimps with a mean weight of around 5.7 grams while shrimp farms in the coastal plateau were around 4.3 grams. However, they argued that the ecological services that mangroves provide outweigh the potential value of larger shrimps from farms in mangrove areas. Therefore, they concluded that in the long-run, shrimp farming in the coastal plateau is less harmful on mangrove conservation and more economically advantageous based on the ecosystem services provided by the mangroves (Tenorio et al. 2015).

With the formation of protected areas and conservation laws, mangroves deforestation rates have decreased, but mangrove deforestation still continues worldwide with a rate of 1 to 2% every year (Thornton & Johnston 2015). Thus, it is important to raise awareness of the benefits and services that mangroves can provide to foster awareness of why it is important to conserve mangroves. In addition, it is also important to consider the problems that mangroves are facing, so that these can be addressed properly in a way that would benefit the ecosystem and not harm a country's economical profit.

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