Mangroves and Their Impact on Small Communities

Dorothy Yeung

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Abstract

The term mangrove refers to woody perennial plants that can grow in salt water, and to the communities that they form. Mangroves are only found in tropical or sub-tropical areas and so are not native to British Columbia. Although they may not be aesthetically appealing, these plants are vital to the local ecosystems and human communities. Many years of various management practices have depleted mangrove populations leaving local communities vulnerable. Over the past years, there have been many natural disasters that have damaged coastal cities and towns. Therefore, current management practices and strategies such as restoration and conservation will be reviewed. Solutions to management issues like education and communication will also be discussed.

Key Words: vivipary, 2004 tsunami, restoration, conservation, management
**Table of Contents**

Mangroves and their anatomy ................................................................. 4

Location ........................................................................................................ 5

Environment and adaptations ....................................................................... 6

Reproduction ............................................................................................... 9

Importance for animals and marine ecosystems ........................................... 11

Importance for small human communities .................................................. 12

The 2004 Tsunami in Southeast Asia – an example of coastal protection by mangroves .......... 14

Management practices .............................................................................. 15

Recommendations and conclusion .............................................................. 18

Glossary ....................................................................................................... 20

References .................................................................................................. 20

**List of Figures**

Figure 1: Percentage of world mangrove area by country in 2005 .................... 6

Figure 2: Salt and waterlogging tolerance of mangroves and other plants ............. 8

Figure 3: Vivipary in mangroves .................................................................. 10

Figure 4: Changes in world mangrove area from 1980-2005 .......................... 16
Mangroves and their anatomy

The mangrove or mangal, the mangrove community or habitat, (Tomlinson, 1986) is a type of plant or ecosystem that simultaneously lives in salt or brackish water and on land. These are woody plants that can thrive if ideal habitats are present. Mangroves form distinctive ecosystems because of their ability to adapt to saline environments and create a valuable habitat for a variety of animal species. Mangrove ecosystems are highly productive but can also be fragile. Mangrove species are very diverse and they are able to take many different shapes and forms. There are approximately 55 different species (Hogarth, 2007) and although many mangroves look similar, they are all different because they have all adapted differently depending on their particular environments. There are currently five main mangrove families:

- Rhizophoraceae: *Rhizophora, Bruguiera, Ceriops*
- Combretaceae: *Lumnitzera*
- Acanthaceae: *Avicennia*
- Sonneratiaceae: *Sonneratia*
- Palmae: *Nypa fruticans*

The growth of mangroves can occur in many forms. Mangroves can look like tall trees, short shrubs, palm trees without a trunk, or ferns. They can also range from standing and tall to spreading outwards to appearing multi-stemmed (Hogarth, 2007). Depending on productivity, age, and stand structure, stand heights can range from 30 to 40 meters tall.

Mangrove species survival depends on many adaptations. Many species can adapt to their surrounding environments, even in extreme conditions. There are several ways for mangroves to adapt to their immediate surroundings. Mangroves tend to be succulent and thick since this helps with the preservation of fresh water and nutrients. They are typically evergreen plants or plants
that have their leaves intact all year (Hogarth, 2007). Leaves on mangroves have characteristics that serve special purpose. The leaves can have waxy cuticles, hairs, or scales that can help conserve water and cover salt glands and stomata (Hutchings & Saenger, 1987). Most species have aerial roots which are roots that are above ground or water level. These roots serve as mechanical props as they are able to help stabilize their structure, tide fluctuations, aeration and areas where there is salt water or higher amounts of salt in the water (Hutchings & Saenger, 1987) (Kathiresan & Bingham, 2001). Salt for fresh water plants that are not adapted to this particular environment is not ideal as too much can reduce chances of survival due to the lack of ability to adapt and compete with other salt water plants. Therefore, mangroves are able to exclude most salt at the root and secrete excess salt through their leaves or use other strategies to reduce build up of salt in plant tissues. These adaptations and others will be described in detail in the following sections. In addition to these site level adaptations, the global distribution of mangroves is very specific in which they mostly reside in tropical areas. The reason for this specific global distribution will be further explained.

Location

Mangroves are found in tropical areas or subtropical areas all over the world. They can be found in: Central America, South America, Africa, Southeast Asia, and Australia. The single country with the largest area of mangroves is Indonesia, (Food and Agricultural Organization of the United Nations (FAO), 2007) as shown in Figure 1. They are virtually confined to the tropics due to reasons that are unknown. Mangroves are also found mainly in saline waters. They are rarely found in fresh water as they would not be able to compete as well with other plants that reside in fresh water. Some possible reasons for its limited geography can include seedling
dispersal barriers, suitable habitats, or physiological constraints (Hogarth, 2007). Of these reasons, physiological constraints seem to be the more probable explanation (Hogarth, 2007). There are many other reasons as to why mangroves are limited to the tropics, but there is not a single answer that is widely accepted amongst researchers. Many trees have to deal with constraints such as those listed above and others such as tolerating salt and living in waterlogged condition. Only tropical trees however, have to put up with a combination of dispersal barriers, habitat and physiological constraints, salt tolerance and waterlogged conditions. Mangroves are also found mainly in saline waters. They are rarely found in fresh water as they would not be able to compete as well with other plants that reside in fresh water.

![Percentage of world mangrove area by country, 2005](image)

**Figure 1:** Percentage of world mangrove area by country in 2005 (Food and Agricultural Organization of the United Nations (FAO), 2007)

**Environment and adaptations**

The habitats of mangals are varied. Mangroves can live in salt water areas which include the intertidal zone, estuaries, and swamps. They mostly grow in waterlogged soil and in water with fluctuating salinity. Waterlogged soil is a name usually given to soil that is saturated by
groundwater (Hogarth, 2007). Since the soil is saturated, it is difficult for many organisms to survive. Mangroves however, are able to take in enough oxygen and nutrients so that they are able to survive and grow. Temperature is also an important factor for mangroves. There are three major processes that use up the largest amounts of energy; they are salt regulation, salt excretion and root respiration (Hutchings & Saenger, 1987). There are certain temperature ranges that can maximize or cease production. The optimal temperature range varies depending on the area a mangrove is growing in, but the approximate range is about 12°C to greater than 28°C (Hutchings & Saenger, 1987).

Mangroves are highly tolerant of waterlogged soils and salt water (Figure 2). Being exposed to salty environments can be stressful, but mangroves are able to grow well and can even flourish when exposed to salt. There are three main ways in which mangroves can deal with salty conditions. Salt can be excluded, extruded, or accumulated (Parida & Jha, 2010). In salt exclusion, water is taken up by roots but the entry of salt is blocked. Salt extrusion occurs when water and salt are taken up by roots, however salt is excreted afterwards. In many species, salt is extruded through salt glands or cork warts in leaves (Saenger, 2002). Salt can also be accumulated in mangrove tissues. Together with salt accumulation in tissues, some species also deposit salt into the bark and stems of roots and in older leaves (Hutchings & Saenger, 1987).
Figure 2: Salt and waterlogging tolerance of mangroves and other plants (Saenger, 2002)

Root systems are usually located underground. They have many roots and rootlets that extend through the surface of the soil so that they are able to take in the proper nutrients, water, and enough oxygen. They are located underground because of the abundance of the necessary resources that are needed for survival. In mangroves, roots are located underground and also above ground. Above ground roots are usually vertical in orientation and help with gas exchange and provide stability (Kathiresan & Bingham, 2001). Not only do these special root forms increase the intake of oxygen, they are able to cope with the large amount of sediment that accumulates on some sites (Hutchings & Saenger, 1987). These roots can be found at different heights above the water or ground surface where water levels fluctuate. When the tide is high, these roots are submerged by water, when it is low tide, they are exposed. There are many shapes that above ground roots can take. Some include pneumatophores which are long roots that are
shaped like pencils with a tapered end, knee roots which are thick and knob like, stilt roots, and buttresses which are shaped similar to planks that are structured to look like fins. Knee roots are thick and knob shaped, hence the name (Hogarth, 2007). The most common form of roots would be the pneumatophores. Pneumatophores are roots that have breathing pores called lenticels (Tomlinson, 1986). All or combinations of the different forms of roots are found in most families of mangroves (Hutchings & Saenger, 1987).

Reproduction

Offspring from mangroves are very distinctive as well; most are dispersed by water currents or waves. Depending on which species it is, there are different ways in which propagules are produced. For the family Rhizophoraceae, specifically the species Rhizophora, the offspring germinates while still attached to the parent. The seed germinates and the hypocotyl elongates (Tomlinson & Cox, 2000). The cigar-shaped seedling may stay on the parent for several months. During this time, the seedling has chlorophyll and photosynthesizes (Hogarth, 2007). Once the seedling has reached a suitable weight and length, it detaches from the parent tree (Figure 3). There is no dormancy period as occurs in many other plants. This unusual behavior of a seedling is rare and science is still investigating why this process is particular to this plant. The Rhizophoraceae family goes through what is called true vivipary (Tomlinson & Cox, 2000). The seedling directly falls off the parent so there are no seeds to be dispersed. Seedlings dropped into water may be carried by water for long distances and once it has found its place, rooting will occur and growth can start (Hogarth, 2007). Seedlings can be viable for approximately one year if a suitable growing area is not found. The seedling will not root if a suitable growing area is not found and will then continue to be transported by water to another location (Hogarth, 2007). The
fact that seedlings can travel some distance is a reason that contributes to how and why
mangroves are found in some unusual places that are far away from where a majority of them are
found.

Other mangroves, such as *Xylocarpus*, reproduce more conveniently via seed dispersal.
Seed size in mangroves ranges quite a bit from a few millimeters to a large fruit (Hogarth, 2007).
Dispersal is typically via water. Once a suitable place has been found germination will occur
(Hogarth, 2007).

There are many factors that limit mangrove establishment. Mangroves have to be able to
conservate water, find a suitable habitat, and adapt to fluctuations in salinity (Hogarth, 2007).
Timing is an important factor because if the timing and conditions are most favorable, rooting
will occur more quickly. Other factors that will affect the survival of seedlings and establishment
include shading, seedling orientation, soil type, and flooding (Kathiresan & Bingham, 2001).
Importance for animals and marine ecosystems

Since mangrove ecosystems are one of the most productive ecosystems, there are a variety of fauna that they are associated with. Some animals such as birds, deer and monkeys (Kathiresan & Bingham, 2001) live above the water in branches and leaves of mangroves. Small insects feed on leaves and find shelter in small crevices. Not only are the above water structures of mangroves useful for animals, the underwater structures provide food and shelter for marine plants and animals. Mangrove habitats are especially important for fish because they serve as shelter, cover from predators, and areas that are suitable for reproduction (Kathiresan & Bingham, 2001).

An example of an animal that relies on mangrove forests is the small grey false water-rat. Small grey false water-rats depend on mangrove forests for habitat and crabs that live in these forests for food. Since many marine animals, particularly crabs, live in the water around mangroves, the water-rat is able to find an abundance of food (Hutchings & Saenger, 1987). An example of a marine animal that is found in and depends on mangrove forests is the mudskipper (Hogarth, 2007). Mudskippers are specialized fish because they are able to stay out of water for long periods of time. They frequently skip across areas where it is muddy and use their pectoral fins to help them walk and grasp objects. They are mainly carnivorous and feed on crabs, insects, and shrimp for food (Hogarth, 2007). Mudskippers live well in mangrove ecosystems due to the availability of food and a suitable climate that has available water and land (Hogarth, 2007).

Keystone species are species that are important to an ecosystem because there could be major effects if it were not present. Crabs in mangrove forests can be classified as a keystone species (Kathiresan & Bingham, 2001). Digging crabs, for example, can have a great effect on
MANGROVES AND THEIR IMPACT ON SMALL COMMUNITIES

the nutrient cycling and the environment of mangrove forests. When these crabs are digging, they will create burrows that will increase aeration, promote drainage and nutrient exchange (Kathiresan & Bingham, 2001). Mangroves have provided greatly for animals and they too can be considered a keystone species. Mangrove ecosystems are highly productive and are able to support fauna and fauna associates. Without the mangrove ecosystem, many mammals, fish and birds would not be able to survive. In fact, due to the loss of mangrove forests, many species such as the Royal Bengal Tiger and the Chital deer are endangered. Other species such as the wild buffalo, swamp deer, and hog deer have gone extinct (Kathiresan & Bingham, 2001).

**Importance for small human communities**

Mangroves function as a source of protection of the coast against erosion. Without these plants, natural disturbances can slowly erode the land in which humans live. The extensive root systems that mangroves have are able to hold the soil and sediment in place (Sanford, 2009)) so that erosion is either prevented or slowed.

People who live in small communities along the coast depend on resources that are close by. The mangrove is an example of a resource that can be used to produce many products that can be used for personal consumption, sold or exported (Valiela et al., 2001). This resource is also important as jobs are created for people who live in surrounding areas. Mangrove habitats however, are quickly being exploited and reduced due to the amount of harvesting occurring (Valiela et al., 2001). Fishing and the conversion of areas to ponds are threatening mangrove ecosystems as well (Primavera, 2004). The area in which mangroves grow is constantly being exploited for its valuable resources. People living in the surrounding areas should be able to use
MANGROVES AND THEIR IMPACT ON SMALL COMMUNITIES

these resources but they should know how to use them so that they will continue to be sustainable.

The rate at which mangrove forests are depleting is rapid and small communities should become more educated or a management plan should be implemented so that the valuable ecosystems are not being taken advantage of. Tourism in Southeast Asia is growing rapidly and is one of the fastest growing tourist areas in the world (Wong, 1998). Sandy beaches and coastal resorts are increasing in demand. This increase in demand leads to more uncontrolled developments and results in greater coastal erosion (Wong, 1998). In order to properly manage coastal tourism, guidelines and management projects should be implemented so that there would not be any uncontrolled developments that would negatively benefit small communities (Wong, 1998).

Mangroves can be turned into timber products. Since mangrove forests are very productive, there are many products that can be obtained from them. Some examples include commercial timber, charcoal, fuel wood, pulp, and tannin (Bandaranayake, 1998). Mangroves can be used for charcoal and fuelwood because of the high calorific value (UNEP-WCMC, 2006). Charcoal is used for cooking and for heat by small industries. Fuel wood is used for cooking as well as for smoking fish and many other products. Pulp is another product derived from mangrove wood and is made mainly for newsprint. A particular species, *Rhizophora*, is able to produce fine tannin that is used for leather work (UNEP-WCMC, 2006). This tannin is mainly produced and used in Central and South America. Non-timber products are also another option that can be feasible. Since mangrove forests are very diverse in terms of marine animals and wildlife, fishing and hunting can be a great non-timber resource to sell or export to other places (Bandaranayake, 1998). All of these products whether timber or non-timber, are providing
employment for the local communities. Without these jobs, the small communities would not be able to survive.

**The 2004 Tsunami in Southeast Asia – an example of coastal protection by mangroves**

Tsunamis are long ocean waves that are created when there is a displacement in a large body of water caused by a disturbance. They are often triggered by earthquakes, volcanic eruptions, landslides, and other disturbances (Intergovernmental Oceanographic Commission, 2008). In 2004, there was a massive earthquake measuring 9.3 on the Richter scale (Kathiresan & Rajendran, 2005) that occurred in the area of the Indian Ocean. From this earthquake, a tsunami was then generated and affected eleven countries. The hardest hit countries were Indonesia, Sri Lanka, Thailand, and India.

Coastal ecosystems have long been neglected. A lot of rich and productive coastal areas are being turned into infrastructure and urban areas. Mangrove ecosystems are not highly thought of when it comes to human protection and valuation. Life on the coast of Sri Lanka, Thailand, and Indonesia was peaceful. Every year, many tourists are attracted to the area for some relaxation. That one day in 2004 was tragic as a tsunami had hit the coast. Hundreds of thousands of people were killed due to this event. After the tsunami had occurred, there was speculation in how coastal ecosystems were being treated. Coastal protection was the main topic of debate. Sanford (2009) has stated that if mangrove ecosystems were being managed more carefully, destruction in some areas could have been minimized. The main priority post-tsunami was to reconstruct coastal ecosystems, mangroves being one of them (Sanford, 2009).
Restoration efforts have now been enforced after the tsunami had hit and the realization of how important mangrove communities are. The immense and extensive root system of mangroves could have had the ability to reduce the large amounts of energy the tsunami created (Sanford, 2009) and a lot of the damage could have been reduced which would have saved many lives.

Management Practices

Mangrove management is complex. Many countries have not had enough experience or guidance on how these ecosystems, should be managed. There are many mangrove forest areas being destroyed for development and by over harvesting. There have been a lot of questions asked as to how we can manage these valuable areas sustainably. Researchers believe that if mangroves are replanted in areas it would help surrounding communities if another natural disaster such as a tsunami hits (Sanford, 2009; Kathiresan & Rajendran, 2005). Research suggested that if mangroves were still in place, damage to the areas that were hit by the 2004 tsunami could have been reduced (Sanford, 2009). We do not know for certain that if we do replant mangroves if there would be any improvements. The stability of the soil is also a factor that is taken into account. How stable the soil is will determine how well or how poorly mangrove seedlings can be planted (Field, 1999). Stability is also a factor when determining the survival rate of mangrove seedlings once they are planted. Many questions remain unanswered and it is up to national governments and international organizations to create better management guidelines to lead countries with coastal ecosystems.

Management practices in the past have been damaging to the mangrove ecosystem, and to the dependent human community. Over the past twenty years, there has been at least 35% of
mangrove area lost (Valiela et al., 2001). Although the amount of mangrove forest lost is very high (Figure 4), the Food and Agriculture Organization (FAO) (2007) has stated the rate of loss has decreased. There has been a substantial amount of mangrove loss in Asia. The amount of harvesting that occurs in these areas is substantial. Exposure to constant and unsustainable harvesting has gradually eroded the coast and reduced the quality of living conditions for the many species and humans. Mangroves are one of the most productive resources available. It is a rational decision to use this resource to its fullest in order to generate profit and increase the country’s economy, but this will require the participation of countries that are willing to make a positive change to conserve mangrove ecosystems.

Figure 4: Changes in world mangrove area from 1980-2005 (Food and Agricultural Organization of the United Nations (FAO), 2007)

Many organizations have taken the effort to enforce restoration efforts into action since the 2004 tsunami. An organization called The International Tropical Timber Organization
MANGROVES AND THEIR IMPACT ON SMALL COMMUNITIES

(ITTO) is an example of an intergovernmental organization that promotes conservation and sustainable management in tropical forests (International Tropical Timber Organization, 2010). They have many restoration sites and community nurseries established all over the world.

A specific example of an approach to mangrove restoration takes place in Sungai Haji Doran, Malaysia. Sungai Haji Doran is a beach in Malaysia that was mismanaged, overexploited, and was going through rapid development (Hashim et al., 2009). A lot of over harvesting and clear-cutting was occurring especially along this area of the coast where mangrove forests resided. The dominant mangrove species in the studied area is *Avicennia marina*. Since these areas are now exposed, there have been many storms and minor natural disasters that have gradually eroded the coast. Without the existence of mangroves, the coastline is continuing to recede more rapidly. Hydrology assessment was an important key to the restoration project because observations show that the degradation is due to hydrology issues. Younger plants need to be flooded by saline water frequently in order to achieve successful rehabilitation (Field, 1999). Hydrology is defined by the depth, duration, and the frequency of flooding (Hashim et al., 2009). The main goal of this project was to rehabilitate the coast. There were two main objectives stated in this restoration project as well. The first was to improve sediment levels that could provide the right hydrologic regime. The second was to restore mangrove forests so that the ecosystem would become sustainable and is able to function similarly to a natural mangrove ecosystem. The area would be restored by replanting mangrove seedlings. However, the area being replanted has soil that is too loose for proper planting and would lead to seedlings being washed away. Therefore, pre-grown seedlings were going to be planted into coir logs first. Coir logs are made from coconut fiber and seedlings are planted in it. Once the seedlings are established in the coir log, the log would be planted into the desired area. Overall, this
MANGROVES AND THEIR IMPACT ON SMALL COMMUNITIES

experiment seemed successful as about 30% of the seedlings that were planted had survived. The experiment is still ongoing and further monitoring has to be completed before a final conclusion is drawn. Experiments like this are successful but are also costly. However, successful experiments such as this one can make way for more successful projects that are more cost efficient.

**Recommendations and Conclusion**

Baba (2004) identified three strategies we adopt to improve conservation and management of mangroves. They are to conserve existing mangroves in areas that have little current use, manage exploited areas via sustainable utilization, and rehabilitate damaged areas. Ways to accomplish these three strategies are to research, exchange information with others, and to have the International Society for Mangrove Ecosystems (ISME) play a role in helping with conservation, fundraising, and providing information (Baba, 2004).

There are many challenges to improving management practices. The reliability of data and statistics is one problem that has been of concern. Because of poor management, data that is collected could result in many inaccuracies causing the data to be unreliable (Sanford, 2009). Funding is also a problem (Baba, 2004) because the amount of monitoring and planting that needs to take place is quite expensive. Approximate planting costs regarding Sungai Haji Doran, Malaysia was about USD $25 000 per hectare, while monitoring costs were about USD $37 000 per hectare. Total costs of one project can add up to USD $225 000 per hectare or more (Hashim et al., 2009). There are also not enough people who are willing to make changes and decisions in order to move forward for better management. The key to successful and sustainable management is cooperation, communication, and the exchange of information (Baba, 2004).
Countries need to be able to communicate with others in order to learn new things and from mistakes. Improvements to education could be done by implementing classes for people around the community to take so that they are able to learn the basics of maintaining and sustaining ecosystems. Communication can be improved by allowing communities to gather and discuss current situations regarding mangrove ecosystems. The discussion can then be brought to the attention of their government who can then continue communication with organizations or other countries.

Throughout the many studies regarding management practices and conservation that I have read, I have found that there are many countries who are trying to replant and restore mangrove habitats. Many different approaches have been attempted but many are not successful. I think that one of the main problems with restoration is the hydrology issue and the significance of soil stability. Suitable water conditions are the key to successful mangrove growth. Without a proper assessment of hydrology in the area, there would be no point in trying to restore mangrove habitats. Replanting seems to be a process that is successful in restoration. As long as the step of site selection is done carefully, replanting will continue to be successful. Utilization guidelines should also be implemented in areas where mangroves are still intact. Communication, education, research and aid from other countries with better management are also important for progress in restoration and conservation. Mangrove forests have been overexploited for many years. Restoration and conservation will take many more years. It will take time and cooperation but I think that these forests can be restored to a sustainable ecosystem.
Glossary

Brackish water: water that has a mixture of saline water and fresh water

Mangal: a mangrove community or habitat

Vivipary: condition when the sexually produced embryo of the seed continues development without dormancy into a seedling while still attached to the parent plant

Hydrology: the depth, duration, and the frequency of flooding

Hypocotyl: part of the germinating seedling of a seed plant; the axis that is below the cotyledons (leaf of the embryo of a seed plant)

Propagule: any plant material used for the purpose of plant propagation

References


