Reforestation without Restoration: A case study of local perspectives of mangrove genera diversity and their use in reforestations

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Abstract

This case study was used to identify local stakeholder perceptions and knowledge of mangrove species in the Saloum Delta of Senegal, West Africa, with regard to their anthropogenic use, ecosystem services provided, and utilization in local management practices. This information is intended to be used to promote effective resource management through protection and reforestation of the mangrove ecosystem. Qualitative interviews consisting of semi-structured, open-ended questions were recorded and used to identify trends among local stakeholder responses. Results suggested that mangrove species occupy different niches in the natural and anthropogenic realms indicating that future research is needed on how we can prevent the loss of these species and what factors can increase the likelihood of success in reforestations involving lesser-known mangrove species. It seems that many reforestation projects are being conducted by outside organizations at large spatial scales, and it is not certain if the appropriate attention is being made to study the potential impacts. Responses suggested that the goals of these outside actors do not necessarily reflect the goals of local communities, and as of now, little is known of the effect mangrove reforestations have on biological and socio-cultural diversity. Thus, the reforestations could result in negative, long-term implications for the ecosystem, including cryptic degradation and decreased species diversity, which could endanger the well-being and economy of local communities. Further research is needed to fully understand the complexity of mangrove ecosystems, while considering the resources, services, and values mangroves provide the local communities.
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**Contents**

List of Figures and Tables 6  
1. Goals and Objectives 7  
2. INTRODUCTION 8  
   Senegal, West Africa 11  
   Mangrove Ecosystems 20  
   Mangrove Importance 21  
      a. Ecosystem Services 21  
      b. Socio-economic Services 25  
   Threats to Mangroves 28  
3. LITERATURE REVIEW 33  
   Mangrove Reforestations in the Saloum Delta 33  
      Background 33  
      Importance 37  
   Past Reforestations and Local Management Practices 39  
4. METHODOLOGY 42  
   Study Area 42  
   Data Collection 44  
   Data Analysis 47  
5. RESULTS 48  
   Local Perspectives of the Status of the Saloum Delta 48  
   The Importance of Mangrove Ecosystems to Local Communities 52  
   Reforestations in the Saloum Delta 60  
   The Roles of Various Stakeholders 61  
6. DISCUSSION 66  
   Protecting the Saloum Delta and its resources 66  
   Reforestations in the Saloum Delta 70  
   Coordination among stakeholders 73  
7. LIMITATIONS AND FUTURE STUDIES 77
8. CONCLUSIONS

Literature Cited

Appendix

1. Sample Photos of Mangrove Genera
2. Perception of Mangrove Genera Interview Script
List of Figures and Tables

**Figure 1:** Location of Senegal in the continent of Africa  
**Figure 2:** A map of Senegal divided by administrative region  
**Figure 3:** Photo showing morphological units of mangrove forests  
**Figure 4:** Photos of birds species found in the Saloum Delta  
**Figure 5:** Photos of local fishing practices in the Saloum Delta  
**Figure 6:** Annual rainfall deviation in the Saloum Deltas  
**Figure 7:** Photos of recently planted *Rhizophora spp.* propagules  
**Figure 8:** Map of the Saloum Delta with villages where interviews occurred highlighted  
**Figure 9:** Sources of mangrove degradation both natural and anthropogenic  
**Figure 10:** The importance of mangroves and associated groupings  
**Figure 11:** Correspondence analysis of mangrove genera and associated groupings  
**Table 1:** Status and trends in mangrove area in Senegal, West Africa  
**Table 2:** A table of statistics concerning perspectives of mangrove importance  
**Table 3:** Participants who mentioned mangrove genera  
**Table 4:** List of participating actors in mangrove reforestations in Senegal
GOALS AND OBJECTIVES

The purpose of this research was to identify local stakeholder perceptions and knowledge of mangrove species in the Saloum Delta of Senegal, West Africa, with regard to their anthropogenic use, ecosystem services provided, and utilization in local management practices. This information would be used to promote effective resource management through protection and reforestation of the mangrove ecosystem. In my study, I sought to determine how local communities and organizations perceive local mangrove species and how those perceptions affect management decisions with regard to the mangrove ecosystem. My objectives were to (1) assess local perspectives and knowledge of mangrove species; this includes assessing their familiarity with each species, and characterizing trends in perceptions of the role each mangrove species in the community and the environment; (2) determine the role of local stakeholders in the management of mangrove species; this involves identifying trends in the protection, controlled harvest, and reforestations of different mangrove species. With regard to mangrove reforestations, I also sought to identify what species were being used and what factors affected those decisions.
INTRODUCTION

Since the end of the 1960s, the Sahelian drought has severely impacted the vegetation of West Africa, with only somewhat wetter conditions in the 1990s, and the drought is the greatest cause of Senegalese mangrove degradation (Conchedda et al. 2011; Diop 1990; Marius 1995). Frequent drought, shorter rainy seasons, and decreased total rainfall have led to salinization of Senegal’s mangrove estuaries creating problems for species that cannot withstand hypersaline conditions (Marius, 1995; Mikhailov & Isupova, 2008; Diop et al. 1999). Before this period, mangroves covered three million hectares of the West African coast, but with the addition of stresses from mangrove exploitation for their wood, deforestation for aquaculture and agriculture, and human encroachment, less than one-third of the mangrove area remains (Sandbrink 2010). Senegal alone has experienced the fourth largest loss of mangrove area in Africa over a span of 25 years (Table 1) (FAO 2007). In fact, in the northern portion of the Saloum Delta (near Foundouigne), mangrove forests have been completely lost due to drought (Diouf 1996).
Table 1. Status and trends in mangrove area in Senegal, West Africa (FAO 2007).

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<td>1980</td>
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<td>127,000</td>
<td>115,000</td>
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<td>1990</td>
<td>145,000</td>
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<td>2000</td>
<td>-1,800 (-1.3%)</td>
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In developing nations, such as Senegal, human populations are predicted to experience the most rapid growth (Alongi 2002). Most mangrove forests are in tropical developing nations that whose residents are often unaware of or unable to consider the economic value of mangroves as a natural resource (Alongi 2002). As a result, mangroves are expected to continue experiencing a myriad of problems, including erosion, poaching, unsustainable fishing, and woodcutting (Diop et al. 1999). In fact, Kaolack, one of Senegal’s most populous regions and the largest city located next to the Biosphere Reserve of the Saloum Delta (RBDS) receives a large portion of its wood and firewood (as well as other forest products) from the mangrove forests in the RBDS (Diop et al. 1999). Overexploitation of mangroves (Rhizophora spp.) from woodcutting has been observed due to the need for firewood (the most essential need) and wooden furniture and the local populations often supply private actors and saw mills with mangrove wood (Diop et al. 1999). Human activities have been shown to reduce mangrove surface area coverage in other areas of Senegal as well (Diop et al. 1997).

Ten percent of Senegal’s total land area is in the Saloum estuary, which drains the Kaolack region. The estuary’s fisheries are becoming increasingly important with the decline of agriculture, Senegal’s main activity, due to decreased soil fertility and damage from wild animals in neighboring parks (a source of contention between local populations and park authorities) (Diop et al. 1999). Yet, the fishing industry has been waning since the 1970s, with the annual catch dropping from 30,000 tons to 10,000 tons by the 1990s (Diop et al. 1999). This drop mainly stemmed from non-traditional, commercialized fishing practices that were adopted after Senegal gained its independence from France. This centralized management of the industry has proven to be unsustainable and contributed to the deterioration of the aquatic ecosystems. Since then a more community-based fisheries management program has been implemented in Senegal.
Traditional methods are not always effective, however, as has been observed with oyster collection. Typically, oysters grow on the roots of *Rhizophora spp.*, which are cut during harvesting that negatively impacts vegetative growth (Diop et al. 1999). Local populations also burn fields to clear them for other activities, such as cultivation and apiculture, which result in out-of-control bushfires that contribute to mangrove degradation (Diop et al. 1999). Mismanagement of these natural resources has resulted from local populations’ lack of information and awareness, which is why raising awareness has become a focal point for organizations trying to boost sustainable management of natural resources in developing nations (Diop et al. 1999).

A large amount of time and effort has been spent restoring the mangrove ecosystems in the Saloum Delta through mangrove reforestation projects. Many actors have participated in these reforestation projects, including local communities and international non-governmental organizations. Local government organizations include the Forest Service (Euxe Foret) and Senegal’s Ministry of the Environment. International involvement includes organizations such as OCEANIUM, World Wildlife Fund, Wetlands International, the Japanese International Cooperation Agency, and the United States Peace Corps. Local individuals and organizations also work independently and with these organizations to conduct reforestation projects, including local women’s groups, villages and village committees.

**Senegal, West Africa**

Senegal (14 00 N, 14 00 W; Fig. 1.1) lies on the western most point on the continent of Africa bordered by Mauritania (North), Mali (East), The Gambia (lies within), and Guinea-Bissau and Guinea (South). Its total land area is 196,722 km². (slightly smaller than South
Dakota) with a population of 14.3 million (www.cia.gov). It has many different ethnic groups, although the main groups include the Wolof (38.7% of the total population), Pular (26.5%), Serer (15%), Mandinka (4.2%), Diola (4%), and Soninke (2.3%). The major religions are Islam (95.4%; four Sufi brotherhoods) and Christianity (4.2%; Roman Catholic) with some animism (0.4%) (www.cia.gov).
Figure 1. Senegal (highlighted in green) is located on the westernmost portion of the African continent. (The World Factbook 2017).
The country is divided into 14 administrative regions, which are often named for that region’s largest city: Dakar, Thies, Diourbel, Saint-Louis, Louga, Matam, Tambacounda, Kedougou, Kolda, Sedhiou, Ziguinchor, Kaffrine, Kaolack, and Fatick (Fig. 2).
Figure 2. A map of Senegal divided by administrative region (By NordNordWest, United States National Imagery and Mapping Agency Data, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=7820529).
Senegal gained independence from France on April 4, 1960 and has since become a presidential republic, currently under President Macky Sall of the Alliance for the Republic-Yakaar party (www.cia.gov). The Senegalese economy is comprised of mining, construction, tourism, fisheries, and agriculture. Notable natural resources include fish, phosphates, and iron ore. Of its available land, 46.8% is used for agricultural purposes, 43.8% is forestlands, and 9.4% is used for other purposes. Its main exports are phosphate, fertilizer, agricultural products and seafood (www.cia.gov).

Senegal’s climate is hot, dry and tropical; and is characterized by a rainy season (May to November) and dry season (December to April). Beginning with the Sainte-Helene anticyclone in the South Atlantic, a monsoonal flux determines the rainy season in Senegal; the duration of which is related to the movement of this tropical front (Diop 1990). Current environmental issues include deforestation, desertification, overgrazing, overfishing, soil erosion, and poaching of wildlife.

Along the coast of West Africa, mangroves are found from Senegal down to Sierra Leone (Cormier-Salem 1994). Most of the mangroves in Senegal are in the southern part of the country in areas known as the Casamance (located below the Gambia) and Saloum (located above the Gambia) (FAO 2007). The Saloum Delta encompasses approximately 210,000 ha made up of mangrove-tidal channels and low tidal flats (Giulia et al. 2011), and includes the Saloum Delta National Park. It is located 70 km west of the city of Kaolack and encompasses over 76,000 ha of mangroves and small islands making it the second largest national park in Senegal (Diop et al. 1999). Registered with the World Network of Biosphere Reserves, the Saloum Biosphere Reserve (RBDS) is formed by three groups of islands and consists of four areas: the surrounding mainland regions; the mangrove-fringed tide channels; the mangrove forests themselves; and the
maritime area, which extends beyond the line of 6 m depth to the open ocean. The Saloum and Casamance estuaries both have semi-diurnal microtides (maximum tidal range ~2 m) characterized by inverse salinity gradients; meaning higher salt concentrations are found closer to the landward side of the spectrum (Diop 1990). The islands are home to small, fishing villages that rely on the natural resources the mangroves provide (Diop et al. 1999). This park is particularly important in hosting a variety of migratory bird species and other wildlife including deer, antelope, spotted hyenas (Crocuta crocuta), common teals (Anas crecca), monkeys (family Cercopithecidae), Atlantic humpback dolphins (Souza teuszii), West African manatees (Trichechus senegalensis), and Green sea turtles (Chelonia mydas) that bury their eggs on the peninsula (Diop et al. 1999), thus attracting many foreign (typically European) tourists.

There are seven species of naturally occurring mangrove trees recognized along the west coast of Africa: Rhizophora mangle, R. racemosa, R. harrisonii (a possible hybrid of the previous two), Avicennia germinans, Conocarpus erectus, Laguncularia racemosa, and Acrostichum aureum (FAO 2007) with R. mangle being the most dominant species (Sakho 2011). These mangroves are often found in large river deltas, on tidal flats, along sheltered coastlines, and in lagoons, and can reach several kilometers inland (FAO 2007). The Rhizophoraceae (red mangroves) can be found farther from the shore and prefer salinity ranges of 20-30 PSU (Practical Salinity Unit). They are therefore less salt-tolerant than Avicenniaceae, which can tolerate more than 50 PSU (Sakho 2011) and is found closer to the bank or behind the “tanee”, or barren area. Three morphological units exist in mangrove forests; the first being the mangrove tidal channels. The second is the mudflat, which is linked to deforestation and made up of fine-grained sediments (<63 mm) (Sakho 2011). The third unit is a barren area, referred to in Wolof as the “tanee”. This area is hypersaline and typically lacks vegetation. It often
experiences annual periods of flooding and desiccation (Marius 1985). Taking a walk along the “tanne” allows one to view these morphological units, and the geographical separation of mangrove species and strands (Figure 3).
Figure 3. Picture showing mangrove forests (left), hypersaline “tanne” (middle), and non-mangrove vegetation (left).
Mangrove Ecosystems

Mangroves represent the only forests between the land and sea (Alongi 2002). They have been defined as tree-like or bushy vegetation found in marine or fluvial floodplains along tropical coasts (Marius, 1985). The trees themselves are the defining feature of these ecosystems and therefore the term “mangroves” often refers to both the organism as well as the ecosystem. Mangroves are woody halophytes meaning they are trees that can survive in salt water. They develop best in tropical estuaries and inlets because low wave energy and shelter allow for fine sediment to settle, thus creating conditions ideal for root establishment and growth (Alongi 2002). Mangroves have many unique characteristics, some of which allow them to thrive in these environments including viviparous propagules dispersed by tides, aerial roots, rapid rates of canopy production, lack of an understory, lack of growth rings, wood comprised of narrow, densely distributed vessels, highly efficient nutrient retention mechanisms, salt-tolerance, and the ability to maintain water and carbon balance (Alongi 2002). Their roots allow them to thrive in waters with high, fluctuating salt concentrations and temperatures, and waterlogged, anaerobic soils (Sandbrink 2010).

Along coastlines worldwide, mangroves cover a total surface area of more than 150,000 square kilometers, representing three quarters of the world’s tropical coastline (Spalding et al. 1997, Wilkie and Fortuna 2003). This distribution makes them one of the most productive natural ecosystems (FAO 2007). Productivity is primarily dominated by the trees themselves and bacteria found in the sediment, which aid in the decomposition of mangrove vegetative material (Alongi 2002; Holguin et al. 2001). The factors controlling mangrove distribution include climate, coastline geomorphology and sedimentology, tidal range; the degree of fluvial freshwater influence, the local hydrological regime (Woodroffe, 1992) and in some cases the
hydrogeology (Wolanski, 1992). Perpendicular to the shoreline, mangroves grow from mean sea level to highest spring tide and the species composition typically changes sequentially parallel to shore (Alongi 2002). The zonation of the trees and other associated species is believed to stem from salinity, nutrient content, soil type and chemistry, physiological tolerances, predation, and competition (Alongi 1992). Earlier studies conducted on mangrove forests have noted that mangroves prefer mudflats with aerated soil (redox potential -280 < +70 mV, dependent on depth of measurement), with a neutral pH of approximately 6.7, brackish (where salt and freshwater mix) river water with interstitial water salinity around 40.1 ppt (parts per trillion), and the intertidal zone should be periodically flooded less than 30% of the time (Sandbrink 2010).

Alongi (2002) notes that mangrove stands follow a natural series of phases over time, from an initial pioneering stage followed by rapid early growth and development, to maturity, senescence and finally death. This natural progression is supported by data from French Guiana where Fromard et al. (1998) measured the structure, biomass and stand dynamics of several mangrove species. Their data showed a natural development of mangrove stands with a relationship between stem density and estimated forest age.

**Mangrove Importance**

a. **Ecosystem Services**

In 1998, the mean monetary value of mangroves was estimated to be US$9,990 ha⁻¹yr⁻¹ or approximately $180 billion (Alongi 2002). Mangrove forests protect coasts by forming physical barriers that help disperse wave energy from tidal swells, storms, and tsunamis and promote soil deposition by trapping fine sediment (Saad et al., 1999; Kathiresan and Rajendran, 2005; Alongi, 2008; Yanagisawa et al., 2009; Sandbrink 2010). This soil depletion and retention results when
the trees stop wind and wave energy while the roots of the trees hold the soil in place and contribute to sediment deposition. The value of this ecosystem service is difficult to calculate. A study conducted in Bangladesh found that it was possible to convert low elevation, barren land to high elevation, fertile land through enhanced sediment deposition from planting 150,000 hectares of differing mangroves species. Of those, 150,000 hectares, over 60,000 hectares of this restored land can now be used for agriculture and is worth US$800 ha⁻¹ yr⁻¹ (Saenger and Siddiqui 1993). With the knowledge we now have on global climate change leading to a rise in sea level, the barriers that the mangroves form may become increasingly important to protect the shorelines from increased strong wave action and flooding (Sandbrink 2010) that we have already devastated coastal communities, and to protect water quality for coastal communities and local biota (Sakho 2011).

In 2009, participating countries met in Barcelona to hold talks on climate change. During these talks, it was noted that the degradation of carbon-rich wetland areas in Africa like mangrove swamps has caused alarming levels of greenhouse gas emissions (Sandbrink 2010). This presents a major problem as greenhouse gas emissions are linked to global climate change. Mangrove trees fix carbon from the atmosphere and the high productivity of older mangrove forests underscores how important they are in storing carbon long-term. Mangroves sequester carbon beyond ecosystem requirements, with excess carbon embodying 40% of net primary production. When estimating photosynthetic production, mangroves are usually more productive than saltmarshes, seagrasses, macroalgae, coral reef algae, microphytobenthos, and phytoplankton making them one of the most productive plants in the ocean (Alongi 2002). This ultimately drives the structure and function of mangrove food webs (Alongi 2002). These food
webs are linked to adjacent ecosystems, such as coral reefs and seagrass beds, and influence mangrove community composition (Alongi 2002).

Although the level of mangrove tree diversity is typically low, these ecosystems play host to a large diversity of animal and plant species. Perhaps their most noted importance is the role they play in providing habitat, refuges, and nursery grounds for aquatic species, insects, and nesting sites for migratory birds (Sandbrink 2010; Alongi 2002; Lewis et al., 1985; Rönnbäck et al., 1999; Nagelkerken et al., 2008; Cannicci et al., 2008; Lopez-Medellin et al., 2011; Sakho 2011). Many coastal species, including juvenile fish and shrimp, spend the critical early stages of their lives in the waters of mangrove forests whose structural complexity creates microhabitats that can be used as refuge (Lewis et al., 1985; Rönnbäck et al., 1999; Nagelkerken et al., 2008; Alongi 2002; Bosire 2008). In fact, compared to other estuarine habitats, the densities of juvenile fish are much higher in mangrove estuaries (Alongi 2002).

Of notable importance to the mangrove ecosystem are the diverse species of crabs, which collect and consume leaf litter and recycle nutrients within mangrove forest soils, and bioturbate the forest floor, which facilitates microbial decomposition. Grapsid crabs prey on mangrove propagules and thereby influence the distribution, abundance and succession of mangrove tree species (Alongi 2002). Mangrove ecosystems also have spatially and trophically complex bird communities including up to eight feeding guilds (granivores, frugivores, piscivores, aerial hawksers, and hovering, gleaning, fly-catching and bark-foraging insectivores) (Figure 4). Sea turtles, and mammals such as monkeys, flying foxes, dolphins, manatees, and otters are present as well (Alongi 2002). The plethora of unique and interesting flora and fauna often attracts tourists who come to see these animals and the beautiful scenery around them.
Figure 4. Photos of various bird species found in the mangroves of the Saloum Delta (2015-2016).
b. Socio-economic Services

The socio-economic importance of mangrove goods and services has been well-documented and includes a multitude of natural resources, including wood, fish, shrimps, crabs, oysters, salt and traditional medicines, all of which local communities use to sustain their livelihoods (Walters 1997; Walters et al. 2008; Bosire 2008; FAO 2007; Giulia et al. 2011; Pacheco 2012). In 2006, a questionnaire-based socio-economic study conducted in the Philippines proposed the mangrove was directly benefiting local incomes in the region of $564–$2,316 ha\(^{-1}\) yr\(^{-1}\) (Walton et al. 2006a). Contributions to the annual income include mollusk, crustacean and fish catches from within the mangroves (294 kg ha\(^{-1}\) worth $213 ha\(^{-1}\)), tourism ($41 ha\(^{-1}\)), timber ($60 ha\(^{-1}\)) and near-shore coastal mangrove associated fish (from 10% to 276 kg ha\(^{-1}\) worth $250 ha\(^{-1}\) to 80% to 2,204 kg ha\(^{-1}\) worth $2,002 ha\(^{-1}\)). The rise of interest in carbon credits could also raise an additional income of $163–$198 ha\(^{-1}\) yr\(^{-1}\) (Walton et al. 2006a). A more recent study conducted by Giulia et al. (2011) in Senegal used survey and census data to conclude that profits from mangrove resources make up about one third of the per capita income among communities living in the deltas.

Communities living near mangrove forests often rely on them as a source of wood for building houses, huts, fences, matting, scaffolds, and for cooking and heating. Mangrove wood is also used to produce charcoal, furniture, bridges, poles for fish cages and traps, boats, alcohol, medicines, and tannins and resins for dyeing and leather making (Kathiresan & Bingham 2001; Pacheco 2012; Alongi 2002; FAO 2007). Mangroves are often planted to generate income from their timber. Matang, Malaysia has one of the best-managed mangrove plantations, sustainably harvesting 17.4 tons ha\(^{-1}\) yr\(^{-1}\) of mangrove wood over a 30-year growing cycle (Bosire 2008).
Local communities often use mangrove strands and associated waterways as sites for the small-scale cultivation of shellfish, finfish and crustaceans (Alongi 2002) and governments are taking note of the role that mangroves play in improving these nurseries and fisheries (Bosire 2008). A study done by Walton and Le Vay (2006), they found that a 7-ha area in the Mekong Delta of Vietnam, when planted with Rhizophora species in 1995, could yield an annual timber harvest rate of 143 kg ha\(^{-1}\) yr\(^{-1}\) valued as $363 ha\(^{-1}\).

Mangroves also have spiritual and medicinal value and are used in the production of traditional medicines. For example, R. mangle (present in Senegal) contains triterpenoids that contain insecticidal properties and can be used in controlling diabetes (Bandaranayake 2002). In fact, studies of mangrove chemistry have suggested that they may be a source of novel compounds that could be used for medicinal and agrochemical purposes (Bandaranayake 2002).
Figure 5. Left photo shows a man mending a fishing net with the help of his sons (and translator). Right photo shows a man fishing by slapping the water with a large pole to scare fish into his net.
Threats to Mangroves

Starting around the end of the twentieth century, scientists began noticing a decline in naturally occurring mangrove ecosystems around the world (Bosire 2008). Mangrove forests can be stressed by changes in salinity, tidal inundation, sedimentation and soil physicochemistry, and damage from storms and cyclones (Alongi 2002). In Senegal, infrequent tidal inundation and evaporation of salt flats has led to an expansion of the barren areas (tannes) and a decrease in mangrove tree abundance that has been attributed to the Sahelian drought (Giulia et al. 2011). When stressed, the susceptibility of mangroves to diseases and pests increases. Drought can also affect the health of mangroves and is often linked to changes in salinity as well. The mean annual rainfall in Kaolack (located in the northern part of the Saloum Biosphere Reserve), from 1933-1963 was 807 mm (Figure 6). This mean decreased to 612 mm between 1964 and 1994 (Diop et al. 1999).
Figure 6. Annual rainfall deviation (in percentage) from the average (1950-2003) across three stations in Saloum (Fatick, Foundiougne, Kaolack). Curve shows five year running mean Source: National Meteorological Institute, Senegal, rainfall data (Giulia et al. 2011).
A study conducted in Micronesia from 1997-1998 found that El Nino Southern Oscillation-related drought resulted in an increase in soil and groundwater salinity (Alongi 2002). The study also noted that due to the lack of rainfall there was a reversal of groundwater flow which caused saltwater from the mangroves to flow upstream into freshwater wetlands.

Coastal erosion has influenced the hydrodynamics of the Saloum delta and has been intensified by progressive breaching of a sandy spit, known as the Pointe de Sangomar, located in front of the mangroves (Diop et al. 1999). This erosion has exposed the mangroves to increased oceanic swells (Soumare 1996), contributed to coastline retreat, and created unstable sandy shoals that migrate and increase sedimentation in some areas (Diop et al. 1999). However, the breaching of the spit has also allowed for the renewal of estuarine waters and has resulted in an increase in marine biodiversity, with notable species of fish that migrate inside including bonefish (*Albula vulpes*), tilapia (*Tilapia guineensis*), herring (*Sardinella maderensis*), butter fish (*Eucinostomus melanopterus*), and Guinean striped mojarra (*Gerres nigri*) (Diouf 1996).

A couple of difficulties arise when attempting to differentiate between natural and anthropogenic-induced threats to mangrove ecosystems. One challenge is due to the lack of long-term data (Alongi 2002). Increased frequency of many of the threats described above, such as changes in salinity, drought, and tidal inundation, could be linked to global climate change, which results from human activities. In 1994, UNEP stated that “impacts of climate change on mangrove use and exploitation are predicted to result in increased flooding and erosion in low lying coasts, intrusion of salt wedge and storms surges and collateral damage” (Alongi 2002). Also, the difficulty in matching attributes recognized with terrestrial old-growth forests points to a problem in determining natural from anthropogenic change in mangrove forests (Alongi 2002).
Studies have shown that rapid growth of human populations and increased pressure on coastal environments results in uncontrolled exploitation of mangrove forests, which contributes to severe losses in mangrove ecosystems (FAO 2007). The main causes of these losses are conversion of mangrove areas for rice production and coastal infrastructure. Advancements in fishing gear and the increased in availability of engines has led to the specialization and spatial expansion of artisanal fisheries located in mangrove ecosystems (Giulia et al. 2011). The cutting of wood for poles and fuel wood (for drying fish, making salt and cooking) also contribute to mangrove deforestation (FAO 2007). Commercial practices include felling for wood products, housing and commercial developments, and modification of natural waterways for bridges and levees. These practices are often imposed from the outside on local communities, especially in developing nations, and are designed to increase the wealth and living standards of people living in coastal areas. However, this exploitation is often on a scale much larger than the local forest can sustain (Alongi 2002).

Human population growth and encroachment in coastal areas often results in increased wastes being dumped into mangrove forests and the adjacent coastal waterways (Alongi 2002). Pollutants such as oils, herbicides, metals, sewage and acids all contribute to the deterioration of mangrove health (Alongi 2002). When exposed to dissolved heavy metals, mangrove trees and their associated microbes display reduced growth (Alongi 2002). Coastal development also increases threats of low-level, chronic pollution from agriculture and industry, which may allow contaminants to seep into groundwater where it makes its way into mangrove forests and the adjacent waterways (Field 2000). Eutrophication from increased boat traffic and coastal waterway use also increase pressure for development and alteration of the waterways (Alongi 2002).
The increase in pollution could also lead to a disappearance of beneficial fauna in the mangroves. The loss of grapsid crabs would negatively affect the growth and natural succession of mangrove forests. Species confined to the mangroves including several species of yellow warblers, mangrove vireo, the mangrove cuckoo, monkeys, flying foxes, dolphins, and otters are often the first inhabitants of mangroves to flee or be harmed by human interference (Alongi 2002). The loss of habitat results in lower population densities and diversity of mangrove-associated organisms (Alongi 2002). The increase in human population growth brings demand in increasing fishing efforts leading to a high probability of coastal waters being overfished. This problem is aggravated by any decline in the health and abundance of mangrove forests (Alongi 2002).

Deforestation is the single greatest anthropogenic threat to the survival of mangroves and the ensuing loss of biodiversity sustained in mangroves, especially in old-growth forests, and they are unlikely to recover for several decades (Alongi 2002; Sandbrink 2010). This degradation also leads to local shortages of wood, salinization of coastal agricultural fields and a significant drop in fish stock (Sandbrink 2010). The health of the mangrove ecosystem and the livelihoods of the people that depend on the natural resources this ecosystem provides are closely linked. Thus, the degradation of the mangroves severely threatens the well-being of the people that depend on them.
LITERATURE REVIEW:
REFORESTATIONS IN THE SALOUM DELTA

Background

Attempts to define ecological restoration of mangrove forests has only relatively recently received attention (Lewis 2000), and prior debate has generated disagreement (Field 1996, 1998; Lewis 2005; Bosire 2008). According to Diop et al. (1999), the purpose of reforestation efforts includes the restoration of mangroves, plantations in bands, protection of habitats and threatened species (by identifying habitats and areas of biological rest), implementation, protection, and soil restoration.

Many different projects previously thought to be restorations have revealed goals that emphasize silviculture for direct natural resource production. This results in planting monospecific plots of rapidly growing mangrove species for future wood harvesting to generate timber, wood chips, charcoal, and fuel wood (Bosire 2008; Field 1998; Ellison 2000). In contrast rare, slow-growing, indigenous species were not replenished (Alongi 2002). Indeed, wood production has led to the greatest success in sustainable mangrove management and may be due to the fact it presents communities with the opportunity for immediate income (Alongi 2002).
Figure 7. Photos of one-year old (left) and recently planted *Rhizophora spp.*
However, this is not what Lewis (2005) defined as ecological restoration, and the resulting low mangrove species diversity could lead to even greater environmental problems in the long-term. Furthermore, in 2000 Ellison conducted a comprehensive review that looked at the goals of mangrove restoration projects to determine if they incorporated the full range of biological diversity and ecological processes of mangrove ecosystems. He also noted the emphasis on silviculture and that few mangrove species were included in these projects. He suggested that data existed to allow for proper mangrove restorations but assessment of structural and functional characteristics must play a role in mangrove restorations. It is not yet known if the loss of mangrove species diversity due to reforestations with only a single species will have unintended negative effects on the ecosystem and in the long-term.

For example, in Senegal and several other African nations, mangrove forest area has increased as a result of restoration efforts and the sustainable management of forest reserves (Clough 1993; Diop 1993) and increased rainfall (Giulia et al. 2011). Using spatial mapping and qualitative interviews, Giulia et al. (2011) concluded that the mangrove area had increased to 49,300 ha (an increase of 2,000 ha or 4%) in the Saloum delta between 1986 and 2006. However, the same study points out that this increase is not necessarily beneficial for the livelihoods of people who live there and that the increase may have unknown consequences on ecosystem services. This situation has been described as “cryptic degradation” (Dahdouh-Guebas et al. 2005; Walters et al. 2008) because it conceals a decline in essential ecosystem services and functionality, and is most likely linked to human-mangrove interactions.

On the other hand, Bosire (2008) stated, “The term ‘restore’ is taken to mean the creation of a sustainable functioning mangrove ecosystem that may or may not resemble its precursor at the very same site.” There is some debate as to what the actual definition of “restoration” should
be. However, the examination of forest compositional data could allow a determination of whether a “restoration” has resulted in a deviation from the precursor forest.

Agreeing with Bosire’s definition, Alongi (2002) noted that restoration of mangrove ecosystems can theoretically be accomplished following cultivation for several centuries. Mangroves can grow and thrive if conditions are optimal, and there is some evidence that replanted mangrove forests can reach the biomass, stand structure and productivity of undisturbed forests within 20–25 years. However, this requires an amount of time that often does not match political, cultural and economic priorities. Apart from studies conducted at Gazi Bay in Kenya (Bosire et al. 2003, 2006; Kairo et al. 2008), there is little available knowledge of the long-term structural development of replanted mangroves in Africa (Bosire 2008) and therefore we cannot be certain as to how long it would take a replanted area to resemble undisturbed mangrove forests. Perhaps a good indication of whether or not a mangrove forest has been restored is by looking at its functionality, which refers to the ecosystem services the forest provides (Walters et al. 2008), including nutrient cycling, sedimentation, providing nutrition and shelter for animals, protecting shorelines, and providing plant products and beautification in an area (Bosire 2008). This functionality would then be compared with the functionality of undisturbed mangrove forests.

The livelihoods of local communities are linked to the health of the mangrove ecosystems upon which they rely. As such, a convergence of development and conservation has recently resulted in what is known as community-based natural resource management (CBNRM), which helps facilitate collaboration between conservation managers and local communities. In this way, sustainability serves to:“(1) redirect labor and capital away from activities that degrade ecosystems; (2) encourage commercial activities supplying ecosystem services as joint outputs;
and (3) raise incomes to reduce dependence on unsustainable resource extraction” (Pacheco 2012). Thus, by practicing sustainable livelihoods, local communities are able to fully participate in sustainably using and protecting their environment while simultaneously stimulating socioeconomic development and equity amongst themselves (Sandbrink 2010).

Community-based natural resource management (CBNRM) is seen as a more cost effective approach than bringing in large development projects and actors because the local communities often have a more intimate relationship with the resource and are more likely to work hard for its conservation, as is the case with mangrove forests (Sandbrink 2010; Ronnback et al. 2007). About 57.9% of the population of Senegal lives in a rural area where they are dependent on forest resources. However, community-based natural resource management projects are still rare, with some examples of mangrove rehabilitation projects noted in the Gambia (Sandbrink 2010). Thus, there is a gap in the knowledge of local population resource use and attitudes, which are necessary for projects to achieve integration of both conservation and sustainability (Pacheco 2012).

**Importance of Reforestations**

There are those who would argue that human intervention through reforestations is necessary for natural regeneration (Bosire et al. 2003) and restoration of the ecosystem (Bornman and Adams 2010) by encouraging conditions that promote mangrove development (Sakho 2011). Indeed, it seems that some coastal wetland environments have become so degraded that it may be impossible for them to recover naturally (Bosire et al. 2003, 2008; Bornman and Adams 2010; Sakho 2011). This is due to a constraint preventing secondary succession, which depends on the availability of mangrove propagules (Bosire 2008). This has
led to the coining of term “propagule limitation”, which indicates that mangrove propagules may be limited in natural availability because of deforestation through development, or hydrologic restrictions or blockages which inhibit mangrove propagules from reaching a restoration site by natural waterborne transport (Bosire 2008). Several papers have also noted that predation may influence propagule availability, thus reiterating that managed reforestations may be necessary (Dahdouh-Guebas et al., 1997, 1998; Bosire et al., 2005b; Cannicci et al., 2008). Other than humans, the only other primary consumer of mangroves is the sesarmid crab, which consume a small proportion of mangrove propagules and vegetation, which may deter recruitment and replenishment of old strands (Alongi 2002). However, the crabs’ role in facilitating nutrient cycling is crucial to the overall health of the mangrove ecosystem.

Secondary succession may take between 15 to 30 years (Sandbrink 2010), so mangrove reforestation efforts can help to speed up the process. Reforestations are aimed at conserving the natural wetlands ecosystems while providing natural resources to the local communities that rely on them. Mangrove reforestation efforts often focus on wood production for timber, pole wood, and fuel wood, but can also help promote fishery productivity, coastal protection, and legislative compliance (Ong 1982; Field 1996; Saenger 2002). As observed in Kenya, an analysis of stand table data from a 12-year-old Rhizophora spp. plantation suggested that reforested plots have the potential to yield 4,864 stem ha⁻¹, which is much higher than a natural stand of the same species (1,796 stems ha⁻¹) (Kairo et al. 2008).

Reforestations are not only important for reestablishing vegetation in an area but also in bringing back beneficial species to the ecosystem. This process is not immediate and takes many years to accomplish but is possible. When mangrove strands become barren there is a clear deficit of mollusks, fish, marine mammal, and bird diversity highlighting the negative effects of
mangrove degradation on biodiversity (Bosire 2008). Commonalities between natural mangrove forests and replanted sites indicate that mangrove reforestations may enhance faunal recolonization (Bosire 2008). In a study done by Walton et al. (2007), for example, a comparison of mud crab populations in replanted, natural, and degraded sites in the Philippines revealed that 16-year-old replanted *Rhizophora spp.* can support densities of crabs comparable to that of natural mangrove stands of mixed species.

Another study by Bosire et al. (2004) found that whereas natural reference sites had the highest fauna densities, taxa richness and composition were comparable among replanted and natural sites. This finding may be an important indicator that successful fauna recolonization is possible after mangrove reforestations. However, silvicultural management often does not consider this factor when assessing the success of restorations (Ellison 2007) even though fauna have a significant effect on ecosystem functioning (Kristensen, 2007; Lee, 2007; Cannicci et al., 2008; Kristensen et al., 2008; Nagelkerken et al., 2008).

**Past Reforestation and Local Management Practices**

Many reforestation projects have taken place in the past, although most failed to accomplish their goals (Sandbrink 2010; Elster 2000; Erftemeijer and Lewis, 1999; Lewis, 2000, 2005) because of inadequate site selection, poor soil preparation, and improper planting techniques (Ellison 2000). This can result from a lack of funding and expertise (Alongi 2002) as well as poor communication and coordination leading to mistakes (Sandbrink 2010). After planting, it is also necessary to replace dead trees, monitor the area, and eliminate pests and diseases (Sandbrink 2010). It is therefore essential to involve local communities in all the
activities throughout the restoration process and explain the importance of monitoring and maintenance to ensure high survival rates. Thus, CBNRM projects offer effective means to implement restoration projects because they are inherently rooted in local community involvement.

The site selection process is extremely important to the success of these projects. For example, high salinity can negatively affect propagule survival (Sandbrink 2010). Although some species are more halo-tolerant, high salt concentrations cause seedlings to experience extreme water stress (Sandbrink 2010). Many attempts have been made to reforest sites that are highly saline with both tidal waters and soils very low in oxygen and nutrient content that are beyond restoration potential (Alongi 2002). Nitrogen and phosphorous are essential to the restoration of mangrove ecosystems and the absence of these elements can limit propagule growth (Sandbrink 2010). Also, the frequency and height of inundation and soil saturation that occurs during flooding is also an important factor (Sandbrink 2010). Without taking these factors into account it is easy to choose a site for reforestation that is not conducive to high survival rates.

It could be argued that among the people most suited to determine the area that would be best to reforest are the local community members who often have a great deal of knowledge of the factors that will result in high rates of survival. It is therefore essential to continue raising the level of awareness of these communities to potential threats to mangrove ecosystems, educate them on proper reforestation techniques, and involve them in any restoration projects. The project ultimately belongs to them because they are the ones who are reliant upon the mangrove ecosystems. When developing projects, development agencies must not only involve local communities but also consider what the communities’ goals and objectives are for the project.
and put them above their own. Without proper knowledge of a community’s thoughts and
attitudes towards a project or situation, any outside action by individuals or organizations could
be detrimental in the long term.
METHODOLOGY

Study Area

This case study was conducted in the southern part of the Saloum delta in the Fatick region of Senegal, West Africa. For two years (2014-2016), I lived in a small village about 10 km from the Saloum delta area. During this time, I communicated with various stakeholders and familiarized myself with specific areas of the mangrove forests. Villages included in this study ranged from Sokone in the north to Missirah in the south (located just above the Gambian border). Due to temporal, financial, and feasibility limitations, I was limited to investigating communities located further inland (East). However, this provided unique insight into an area of the mangrove ecosystem with a high level of human interaction; an area particularly affected by urban development and growing populations. Direct observations were noted of mangrove degradation due pollution, livestock, and construction. Many agricultural areas close to the mangrove forests were observed in this area. As such, these areas were targeted as areas in need of mangrove reforestations. A map of villages where interviews were conducted is shown in Figure 8.
Figure 8. Top photo shows where the Saloum Delta is located in Senegal. Bottom photo is a map of the Saloum Delta with villages where interviews occurred marked with small circles.
The abundance of mangroves ranges from many hectares of barren, sandy spits (mainly in the north) to large, older strands that span for many kilometers further south. The northern part of the Delta is much more dominated by smaller channels and inlets than the large “bolongs” and waterways further to the west and south.

Data Collection

To assess perceptions of mangrove ecosystems and reforestations, a qualitative research methods approach was selected to conduct interviews that could incorporate and capture a wide range of viewpoints. A case-study approach was chosen because it allowed for contemporary phenomena (i.e. mangrove reforestations) to be investigated in a real-world context (i.e. local communities of the Saloum Delta) that the researcher had little to no control over (Yin 1984) and would yield empirical data. A more experimental design would not have been appropriate due to the great number of actors, relationships, processes, and factors involved.

The bulk of the interviews were conducted in July and August of 2016. This period was at the beginning of the rainy season when mangrove awareness campaigns and reforestations would soon be occurring. I conducted interviews using the help of a local translator who conveyed questions in Wolof or French and translated from Wolof or French to English. However, I also could follow Wolof responses closely, which helped with note taking, translation, and identifying discrepancies between the two languages. Interviews were recorded with the use of a recording device. Individual interviews were held in small venues- often the participants house or compound. Participants were selected based on their level of involvement with mangrove forests and mangrove reforestations, such as Euxe Foret (Forest Service) agents and local leaders of mangrove reforestation projects. All participants were required to be 18
years of age or older. Snowball sampling was used to identify and interview other stakeholders living in the area. In order to allow us to cover a larger geographic area, only 3-4 stakeholders were interviewed per village. I also attempted to include participants from various ethnic groups and professions, and include an equal number of male and female respondents.

Before conducting interviews, I applied for and received a category two exemption from the University of Washington Human Subjects Division to carry out this study (HSD Exemption #51700). Individual names and the precise locations of each interview participant were kept confidential during and after the interview process in compliance with this exemption. Upon completion of the interviews, all identifying information was destroyed to ensure participant anonymity.

Interviews were conducted to understand perceptions of individual mangrove species and how those perceptions influence management decisions with regard to harvesting, protecting, and reforesting. Questions were designed to effectively cover and assess the breadth of knowledge possessed by individuals. Questions were semi-structured and open-ended to allow participants to talk about a large range of topics all pertaining to mangrove ecosystems and reforestations. The questions were formulated to exclude opinionated language or bias and to ensure that the researchers did not project an opinion or bias of the topic being discussed. Instead, the questions were designed to allow for respondents to express their own opinions and perspectives without undue influence from the research team. The interview script (Appendix) was constructed to elicit a certain level of response in all interviews so that empirical data could be collected and analyzed. A total of 30 interviews were conducted individually or in a group setting bringing the total number of participants to 40. Interviews lasted on average 38 minutes and ranged from 15-90 minutes. Of the respondents, 27 were male and 13 were female; 28 were
of the Serer cultural group, 10 were Mandinka, and two were Wolof. Most of the respondents were private citizens (33), four worked with local NGOs, and three worked in some form for a Senegalese governmental organization.
Data Analysis

Following the completion of the interviews, recordings were transcribed to computer text, which were then coded using the computer-aided qualitative analysis research software, HyperResearch (Researchware, Inc., Randolph, MA). Coding involves classification of ideas or themes into a systematic order so that they could be analyzed in context (Coffey and Atkinson 1996; Saldaña 2013). The same program was used to identify consistencies and general trends from the interviews through the utilization of frequency reports and the report builder tool, which allowed for trends to be assessed by code name and grouped into categories. When looking at trends in sources of mangrove degradation, individuals were divided between northern and southern villages, and sources were divided between natural and anthropogenic (Figure 9). Categories of mangrove importance included habitat provision, ecosystem services excluding habitat provision, anthropogenic uses associated with wood, and anthropogenic uses associated with leaves and seeds (Figure 11). Coded frequencies and the number of respondents were entered into Microsoft Excel, which was used to graphically represent basic trends (Figures 9, 10, & 11; Tables 2 & 3). A correspondence analysis was conducted using SAS (Statistical Analysis System, Cary, NC) to assess cross tabulations in interviewee responses between mangrove genera and perceptions of mangrove values (Figure 11).
RESULTS

Local Perspectives of the Status of the Saloum Delta

Participants were asked about their thoughts on the status of mangroves in the Saloum delta. Of the respondents who gave a response regarding the relative well-being of the mangroves, there was an even split between those who mentioned that mangroves were doing well or improving (n=7) and those who mentioned that the mangroves were threatened or in trouble (n=7). Some respondents made note of how important the delta had become to the region and worldwide (n=4). When speaking about mangrove species individually, some respondents noted that they believed species of Rhizophora (n=7), Avicennia (n=3), and Conocarpus (n=1) had been more numerous in the past than they were currently.

Responses indicated that there may be several reasons for this perceived decrease in mangrove abundance. Respondents noted that many sources of disturbance, degradation, and deforestation had reduced the number of mangroves in the area (Figure 9). The number of individuals who noted sources of natural degradation did not vary, however, in anthropogenic sources of degradation there was a trend towards a greater number of individuals from northern villages (Figure 9).
Figure 9. Number of respondents that mentioned sources of mangrove. Bar graph (left) splits individuals between northern and southern villages. Pie chart (right) splits individuals between natural and anthropogenic sources.
Drought or a lack of freshwater input can lead to a rise in salt levels. Salinization presents a major problem in terms of restoration because without mangroves the salt level of the land and water increases. This in turn makes it harder to reforest the mangroves that are only salt tolerant to a certain level. One interviewee works with a group that measures salt levels in the surrounding areas, especially when choosing a site for reforestations. He noted that:

“*We have noticed that the level can go from 29g/L to 39g/L. We have noticed that if it is between 29 it can regenerate. If it passes 39 the mortality goes up. Where ever we notice 60g/l there is total degradation. That deserves scientific confirmation.*”

When mangroves disappear from an area it can also lead to increased erosion and sedimentation of nearby waterways. Respondents noted that sedimentation has led to reduced channel depth and sand-dominated soils surrounding the shores. In this way, severe drought can set off a positive feedback loop of factors that make it increasingly difficult to restore the mangrove ecosystem.

Mangroves in the Delta also face pressure from anthropogenic sources including harvesting and alteration of local hydrology. Mangrove wood is very strong and termite resistant making it highly valued material in roof and structure construction. This was the reason most mentioned for mangrove deforestation (n=18), followed by oyster collection and wood for cooking (n=11). Construction of roads and dams in the delta also alters the hydrology of the area and can have negative consequences on the mangrove ecosystems. As one respondent noted:

“At the beginning they were numerous [sic] there was a lot of this kind of species but they did a kind of thing [sic] when they were building this road from Sokone to Karang they blocked the water [sic] here so that [the] construction destroyed all this species. But we used to have a lot of them.”
Some respondents mentioned that the local populations were generally ignorant of the degree to which mangroves are important to supporting local communities and ecosystems (n=2). However, the respondents themselves were chosen because of their knowledge and expertise in working amongst the mangroves of the Saloum Delta. When asked about sources of knowledge of mangrove ecosystems, most respondents referred to their personal experience; i.e., the fact that they had lived or worked in the mangroves (n=21). Others stated that members of their family and their ancestors had taught them about mangroves (n=9) and some mentioned that outside organizations had taught the local communities about the importance of mangroves (n=6).

Indeed, measures have been taken by local actors to change the low-level of awareness in communities by educating them on the importance of mangrove ecosystems and prohibiting illegal harvesting (n=23). One person working with local communities stated that:

“[…] protection goes with awareness and sensitization and training the community of [sic] the protection.”

Protecting mangroves from illegal harvesting is a difficult process due to the large area in need of monitoring and the level of resources and man-power required. Many communities are working with forestry agents to alert them of illegal activity and observation towers have been constructed to monitor people entering and exiting central areas. Some communities have even taken to promoting beehive development in the mangroves because the bees attack individuals that hack at the wood with machetes and disturb the hive.

“We have a protection project of the mangroves. That strategy was making the bee hives in the mangroves to prevent people from destroying them. The bee hives are still there. We have noticed that people don’t cut the mangroves where there are bees. Unfortunately, where there are no bees people are cutting them.”
The Importance of Mangrove Ecosystems in Local Communities

Participants most often mentioned the importance of mangroves in providing habitat and shelter for fish (n=26) and promoting the growth of oysters on their roots (n=25) (Table 2 and Figure 10). Speaking to the association between fish and mangrove forests, one respondent mentioned that:

“I used to be in Foundouigne but now there are no more Rhizophora there so there are no fish, no oysters, no [shellfish]. That’s why I moved here.”

In total, respondents mentioned that mangroves provide habitat for animals 171 times (Figure 10). This includes a large diversity of bird species that take shelter in the mangroves, for example herons and pelicans, leading to well-known bird watching areas, such as “Bird Island.” The role mangroves have in providing ecosystem services including erosion control, salt regulation, and carbon sequestration was mentioned 23 times. Traditional medicine was mentioned 19 times and the aesthetics of the mangroves were mentioned 16 times. This may suggest that the most important factors to local communities are dominated by the income they receive from the natural resources provided by the mangroves, followed by the ecosystem services and medicines they provide, and finally includes a beautiful environment that boosts the tourism industry.
Table 2. A table of statistics concerning respondents’ perspectives of mangrove importance. The table labels the importance, how many times it was mentioned total, how many individuals mentioned that importance, the fraction of respondents that mentioned the importance, the average number of times that importance was mentioned in a single interview, and the range of how many times an importance was mentioned in a single interview.

<table>
<thead>
<tr>
<th>Importance</th>
<th># of Mentions</th>
<th># of Individuals</th>
<th>Fraction of Respondents</th>
<th>Average # of Mentions</th>
<th>Range of # of Mentions per individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oysters</td>
<td>72</td>
<td>25</td>
<td>0.63</td>
<td>2.88</td>
<td>[1,8]</td>
</tr>
<tr>
<td>Fish</td>
<td>50</td>
<td>26</td>
<td>0.65</td>
<td>1.92</td>
<td>[1,6]</td>
</tr>
<tr>
<td>Traditional Medicine</td>
<td>19</td>
<td>17</td>
<td>0.43</td>
<td>1.12</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Shellfish</td>
<td>15</td>
<td>11</td>
<td>0.28</td>
<td>1.36</td>
<td>[1,3]</td>
</tr>
<tr>
<td>Crabs</td>
<td>12</td>
<td>8</td>
<td>0.2</td>
<td>1.5</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Beauty</td>
<td>11</td>
<td>8</td>
<td>0.2</td>
<td>1.38</td>
<td>[1,3]</td>
</tr>
<tr>
<td>Birds</td>
<td>11</td>
<td>8</td>
<td>0.2</td>
<td>1.38</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Promotes Rainfall</td>
<td>8</td>
<td>6</td>
<td>0.15</td>
<td>1.33</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Prevents Salinization</td>
<td>7</td>
<td>7</td>
<td>0.18</td>
<td>1.0</td>
<td>[1,1]</td>
</tr>
<tr>
<td>Prevents Erosion</td>
<td>6</td>
<td>6</td>
<td>0.15</td>
<td>1.0</td>
<td>[1,1]</td>
</tr>
<tr>
<td>Bees</td>
<td>6</td>
<td>4</td>
<td>0.1</td>
<td>1.5</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Tourism</td>
<td>5</td>
<td>4</td>
<td>0.1</td>
<td>1.25</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Manatees</td>
<td>3</td>
<td>2</td>
<td>0.05</td>
<td>1.5</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Monkeys</td>
<td>2</td>
<td>1</td>
<td>0.03</td>
<td>2.0</td>
<td>[1,2]</td>
</tr>
<tr>
<td>Carbon Sequestration</td>
<td>1</td>
<td>1</td>
<td>0.03</td>
<td>1.0</td>
<td>[1,1]</td>
</tr>
<tr>
<td>Prevents Desertification</td>
<td>1</td>
<td>1</td>
<td>0.03</td>
<td>1.0</td>
<td>[1,1]</td>
</tr>
</tbody>
</table>
Figure 10. Graph of the number of mentions and number of participants who mentioned an importance from Table 2. Pie chart shows the combined number of mentions for grouped categories of mangrove importance.
As many respondents mentioned, the mangroves provide “everything the people need.” “Life depends on them,” said one respondent alluding to the people’s reliance on the natural resources derived from mangrove forests. However, the mangroves provide more than just food and income for the local communities. “Mangrove natural resources create jobs and fight against unemployment,” said one leader of a local NGO.

Awareness and importance of individual mangrove genera are summarized in Table 3 and Figure 11. First, it should be noted that the Rhizophora genus was the most well-known mangrove species (100% awareness) with awareness decreasing for species of Avicennia (95%), Conocarpus (77.5%), and Laguncularia (62.5%) respectively (Table 3).
Table 3. Number and percentage of participants who mentioned various mangrove genera.

<table>
<thead>
<tr>
<th></th>
<th>Rhizophora</th>
<th>Avicennia</th>
<th>Conocarpus</th>
<th>Laguncularia</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Participants who mentioned each species (n=40)</td>
<td>40</td>
<td>38</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>Percentage of Participants</td>
<td>100%</td>
<td>95%</td>
<td>77.5%</td>
<td>62.5%</td>
</tr>
</tbody>
</table>
The various codes used to identify the importance of mangrove species were grouped into categories for habitat, ecosystem services, wood, foliage, and other, and were separated by genera. A correspondence analysis revealed which species were associated with a group of codes (Figure 11a). When partitioning $\chi^2 \approx 99\%$ of the variation was explained by two dimensions (Fig. 11a). By looking at the groupings in Figure 11a we can see that *Rhizophora* spp. are more closely associated with their value in providing wood, habitat, and ecosystem services. *Avicennia* lies in between its value as a resource for wood and foliage. All species other than those of *Rhizophora* appear to be more closely associated with their valued foliage than in providing other resources (Fig. 11).
Figure 11. **a** Multiple correspondence analysis of mangrove importance groupings by mangrove species, showing variation across two dimensions. Circles highlight associations between mangrove species and importance group. **b** Corresponding plot of number of respondents, by grouped mangrove importance, that are associated with mangrove species. Mangrove species are shown in italics.
Rhizophora spp. were known for providing habitat, mainly for oysters and fish, which is to be expected as it is the most common species and oysters and fish are one of the most highly valued resources (Figure 11b). However, Avicennia was known for providing habitat to other species, such as crabs and shellfish, which are also collected by local communities. In fact, Avicennia provides special habitat for these semisarid crabs, which dig holes that are thought to aerate the soils and allow rainwater to infiltrate the soil and promote mangrove development. Both Rhizophora and Avicennia were recognized for the ecosystem services they provide, with a greater emphasis in the role Avicennia plays in salt regulation. Many respondents noted that Avicennia was found closer to the bank than Rhizophora spp. The responses indicate the different spatial and ecological niches these two species occupy. The other two species were only mentioned a few times for the roles they play in ecosystem services in that some respondents mentioned that they had the same ecological role as Avicennia.

Both Rhizophora spp. and Avicennia were recognized for their value in providing wood for construction and fuelwood, with emphasis on Rhizophora spp. providing wood for roofs. One interesting difference from the responses is that the leaves and seeds for Avicennia, Conocarpus, and Laguncularia are mentioned much more often than with Rhizophora spp. (Figure 11). The leaves and seeds of these species are often used in traditional medicines given to new mothers who have just given birth, in dyes, and as a paste mixed with millet that was eaten during periods of drought. Conocarpus and Laguncularia were not as recognized or mentioned during these interviews. This was to be expected as many people did not even know of the presence of these two genera.
Reforestations in the Saloum Delta

Most of the respondents who expressed opinions on reforestations in the area were positive (n=14). Respondents noted that the reforestations were important and had been adding a significant number of mangroves back into degraded areas. Some even mentioned that oysters were beginning to grow on the roots of those mangroves planted several years ago, and fish and other animals were returning to the area, which indicates that the mangroves are healthy and growing well.

When discussing important factors that contribute to a successful reforestation project, many respondents knew that the quality of the propagule and the site selection process were important factors. Some communities had been trained on what to look for when choosing a site, with most responses mentioning that high tide must reach the area. It was also mentioned that the project should take place where fishermen and/or livestock would not disturb the propagules. One respondent reported that they went as far as to measure salt levels before conducting reforestations.

However, some respondents made mention that the scope of the reforestations may elicit cause for concern. Several responses noted that outside organizations had reforested “great areas” and “lots of sites” in the past years. Some respondents, particularly in the village of Missirah, said they reforest every year and one respondent said they plant mangroves daily (during the rainy season). This has led to situations such as the following,

“Now we have no place to reforest because from 1998 to now we had many reforestations and many programs want to reforest […] If you reforest all the places then some species may not have a place to live.”
When speaking about reforestations, most respondents referred to *Rhizophora spp.* Whereas everyone had reforested with *Rhizophora spp.*, only 11 participants knew of reforestations with *Avicennia* (27.5%). No one knew of any reforestations being conducted with either *Conocarpus* or *Laguncularia*. Most respondents seemed to think that *Rhizophora spp.* were already dominant in the area with only two respondents thinking it was *Avicennia sp.* that was the most numerous. The reasons given for the common practice of planting with *Rhizophora spp.* include the familiarity of local communities with reforesting with these species, the ease of the process, and the desire to plant these species to promote oyster abundance. *Rhizophora spp.* are also very resilient and adaptable resulting in high propagule survival rates that exceed 90%.

**The Roles of Various Stakeholders**

Mangrove reforestation projects ultimately belong to the local communities involved in the process. Many members are directly involved in the planting of mangrove propagules and some are paid to collect the mangrove propagules for the reforestation. Individual villages may assemble committees that are trained in selecting sites for reforestations, or are responsible for following up with the project and ensuring the protection of the planted propagules. Often, the population is working in conjunction with local forestry agents to conduct reforestations and protect the mangroves from illegal harvesting. For example, the following information comes from a local coordinator for a reforestation project:

“When I was coordinating the mangrove project we got the population involved and then chose the forest agent as the protector of this project. The population was carrying out the activities of the project. The population was organized under a local committee. The local committee was supervised by the forest agent. I myself was just supervising the activities the population was carrying out but all the jobs belong to the population.”
Collaboration also can occur between different villages as was the case when members of the northern city of Foundouigne were brought to villages near the RBDS to witness the benefits of mangrove ecosystems. A reverse exchange also occurred so that members that live in the RBDS would have an appreciation for their environment and have an increased desire to protect it.

Local, national, and international non-governmental organizations are also highly involved in local mangrove reforestation projects (Table 4). They conduct many trainings on how to plant mangrove propagules, and educate local communities on the importance of mangrove ecosystems (n=8). Although many reforestations are viewed by local community members as successful and beneficial, larger NGO involvement has created issues for the projects. One issue is that they do not always take community involvement and objectives into account. For example, one respondent noted that

‘The main issue is that when they come they don’t take the experience of the population-they don’t involve the population. They come with their own objectives. For instance, if it is to do this [the reforestation], the population is not really involved and they have to do their own appropriation in the end. I think that the best approach is the NGOs should work with a local organization that knows [sic] better the action that should be done. They have experience in the specific field. If those [local] organizations are not really trained then they have to train them before they implement the project. The NGOs, before they come, they should have a plan of action, objectives they are [sic] doing, the expected results, and a good plan before. They don’t say “O.K. this is the organization that is here and another organization worked with them so we should too.” No. You need the best plan for work.’

Another participant commented that:

“[…] partners come with their fixed ideas. ‘Here are our objectives and you have to follow this.’
Table 4. Larger actors (both national and international) participating in mangrove reforestations in Senegal.

<table>
<thead>
<tr>
<th>Actor Name</th>
<th>Number of Mentions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceanium (French)</td>
<td>4</td>
<td>NGO</td>
</tr>
<tr>
<td>Haidar El Ali (Senegalese citizen)</td>
<td>4</td>
<td>Former Director of Oceanium and Minister of the Environment</td>
</tr>
<tr>
<td>WAAME (American)</td>
<td>3</td>
<td>West African Association for the Marine Environment</td>
</tr>
<tr>
<td>USAID (American)</td>
<td>3</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>JICA (Japanese)</td>
<td>3</td>
<td>Japan International Cooperation Agency</td>
</tr>
<tr>
<td>Wetlands International (International)</td>
<td>3</td>
<td>NGO</td>
</tr>
<tr>
<td>Cheikh Anta Diop University (Senegalese)</td>
<td>1</td>
<td>A.K.A. University of Dakar</td>
</tr>
<tr>
<td>US Peace Corps (American)</td>
<td>1</td>
<td>American Government</td>
</tr>
<tr>
<td>Global Environment Fund (International)</td>
<td>1</td>
<td>NGO</td>
</tr>
<tr>
<td>PRODDEL (Senegalese)</td>
<td>1</td>
<td>Program of Support to Decentralization and Local Development</td>
</tr>
<tr>
<td>PAPIL (Senegalese)</td>
<td>1</td>
<td>Support for Small Local Irrigation Projects</td>
</tr>
<tr>
<td>YMCA (International)</td>
<td>1</td>
<td>Young Men’s Christian Association</td>
</tr>
</tbody>
</table>
Many organizations clearly have a specific goal of planting as many propagules as possible over as great an area as possible and typically focus on *Rhizophora spp.*, which are the easiest to plant. This is expressed in the following statement,

‘Today, people who do the project of the reforestation they come and reforest everywhere they want […] The first year we had a competition and planted it everywhere. The project came and said, “let’s do a competition.” I know they should be planted in a muddy place but since they said, “Let’s have a competition” we planted everywhere. We knew it wouldn’t grow in certain places but because it was a competition we planted it everywhere.’

However, this trend is in the NGO’s best interest because many of them receive carbon credits. For example, Oceanium is paired with Danone water company, which has brands like Aqua and Evian. This creates conflicts between communities that do not wish to reforest large areas. For example:

“We don’t have great areas. What we have reforested represents this approach. That’s why a lot of NGOs don’t come back is because they can’t get many carbon credits. The strategy the population suggests [the companies] can’t profit and yet it is really important for struggling against the greenhouse effect.”

The organizations often did not conduct a follow up on the success of the project. For example:

“I notice more and more the organizations come and don’t do a study of the impact- the effect the project may have on the ecosystem.”

Another issue that arises through collaboration with large NGOs is the financing of work conducted by local community members who collect and plant the propagules. Financing of work can be beneficial to local communities that have low average incomes to buy things they
typically would be unable to afford. For instance, one community used the extra income to purchase birth certificates for all the children of the village. However, others believe communities should not need a financial incentive to restore and protect mangrove ecosystems because their livelihoods are directly linked to them.

“For a better success, I always avoid paying the population for a job they should do for free.”

It can also create issues for local NGOs that do not have the same level of income or resources at their disposal. When asked about what conflicts arise with paying local communities, one project coordinator mentioned that,

“Problems such as conflicts between local organizations. Because sometimes they get accustomed to being financed. If it happens another NGO comes without finance it will be a problem. It is an issue I have noticed.”

However, finding the means to mobilize people to conduct reforestations and providing protection for the projects remains an issue that needs solving.

One thing is certain, the local communities believe that it is important that they be involved in the process and that their goals are made a priority in management decisions. They want to be able to decide the programmatic approach rather than the NGO. One participant also noted that an increase in communication is essential to solving problems associated with projects. They believe in sharing information and a common vision so that projects can have a unified approach. This is summed up in the local phrase “Nu bokk gis-gis” or “Let’s share one vision.”
DISCUSSION

Protecting the Saloum Delta and its resources

The responses gathered about the status of the Saloum Delta present a mixed bag of attitudes on whether the Delta environment is currently better or worse than they were in the past. These viewpoints reflect what has been observed by previous studies (Diop 1993; Diop et al. 1997; Giulia et al. 2011) and what one can directly observe today. The different viewpoints are also to be expected since different villages have different mangrove abundances and management strategies. This study focused on individuals whose lives were directly connected to the mangrove ecosystem and therefore it is to be expected that the respondents would know of the values mangroves provide. Indeed, it was made apparent that respondents were very aware of the direct link between mangrove trees and the role they play in providing sanctuary to small fish and stimulating oyster development. Because these fish and oysters are such a highly-valued resource for the local communities and much of the country, many local individuals are aware of the importance of protecting the mangrove ecosystems. Other organisms of note mentioned in the interviews included shellfish, crabs, birds, bees, manatees, and monkeys. When grouping the responses to identify the mangrove’s value in providing habitat, we can see that this function is one of the most well-known among respondents (Figure 10).

Habitat provision is also related to another important source of income for the country of Senegal and local communities, which is the tourism industry. Many respondents mentioned how beautiful the mangroves were or mentioned the tourism industry directly. The animals that inhabit the mangroves are part of their appeal. Many tourists go birdwatching and one important nesting site has been termed “Bird Island” due to the great abundance and diversity of bird species that nest there. Tourists are also involved in recreational fishing and enjoy fresh seafood
at local resorts. The Saloum Delta even enjoys a status as a UNESCO World Heritage site due to its large shell mounds that are over 2,000 years old. These mounds have formed stable islets and well-preserved funerary tumulus mounds that serve as examples of traditional human settlement and a sustainable lifestyle of oyster collection and fishing (UNESCO.org).

The ecosystem services that mangroves provide were not mentioned as often by interviewees. However, this should in no way downplay the importance of these services. It seems that respondents who have witnessed a great loss of mangroves are aware of these circumstances having lived through them. The important take away from this is that communities should be educated as to what they stand to lose in the way of precious resources and ecosystem services if they do not protect the mangrove trees.

However, despite all the important roles mangroves play in Senegal, mangroves in the Saloum Delta still face many pressures (mainly human-induced) that need to be addressed. Mangrove trees are highly valued for their wood, and illegal harvesting for fuelwood and construction materials poses a great threat to mangrove trees leading to deforestation. However, many local communities are reducing this pressure by building structures out of cement, creating charcoal, and building improved cooking stoves. The promotion of oyster culture and the practice of scraping oysters off the roots, rather than cutting the entire root off, also help to reduce pressure on mangrove trees. By finding ways to mitigate the use and collection of mangrove wood, local communities can better protect the mangrove resources they rely upon.

Respondents noted that drought, salinization, and sedimentation are all threatening the health of mangrove ecosystems. These processes are all linked together as drought leads to high levels of salination, which stresses mangrove trees. When the trees die, erosion control is reduced and sedimentation results. The combination of drought and highly saline and sandy
soils then makes it extremely difficult to replant mangrove trees and even more difficult to restore the ecosystem to the old-growth dominated habitat that was a nursery for so many species of fish, oysters, and birds. Since restoration in the Saloum Delta is such a difficult task, the top priority in maintaining the health of the ecosystem is to protect it from degradation.

The burden of protecting the mangroves ultimately falls to the local communities as they are the ones directly impacted by its degradation. Interviews revealed that individuals in the communities do not always understand all the ways that they are reliant upon mangroves and that the resource can disappear if they do not protect it. Education efforts and awareness-raising campaigns are attempting to solve this issue simply by discussing the importance of mangrove trees as a keystone functional group that supports the rest of the ecosystem. These trainings and discussions are led by local and international NGOs, and should be continued in the interest of setting up common knowledge and goals throughout the delta regarding the functions of mangrove ecosystems and the importance of protecting them.

However, even with the recent raising of awareness in the area, local populations must confront other threats to the mangroves. For example, a common problem with restoring a system is that it takes time, effort, and resources for effective management and many populations do not have the financial stability to dedicate themselves to overseeing management of the area. Local governments and even village councils require sufficient funds to hire people to protect specific areas of the forest over time. Many communities and individuals rely heavily on harvesting within the mangrove ecosystem as a source of income. This creates a tragedy of the commons situation when the available resource is limited and certain areas and resources are supposed to be protected. Another problem is that many people who do not live in the region travel to the mangroves to harvest fish and oysters. These people often have little regard for the
rules protecting mangroves. They are more likely to cut entire roots to harvest oysters, infiltrate areas of no harvest, and will often harvest the mangrove wood to smoke and cure their seafood catch for transport to areas far from the coast. Constant vigilance is required among the local communities and cooperation with local enforcement agencies. This is not always possible as the Delta covers a very large area making it difficult to protect all the areas.

Local community members are also highly involved in agriculture and are consequently not able to take the time to conduct adequate surveillance needed to minimize illegal harvesting in mangrove forests. This puts a great amount of pressure on local forestry officials who are limited by budget, labor, and other resources to effectively protect the mangrove ecosystems. The French NGO, Oceanium, has attempted to help alleviate this pressure by constructing a large watch tower in an area of the mangroves so that officials can observe a larger area and monitor the people coming in and out of the protected area. However, such large projects are not always feasible. In lieu of such large projects, a greater amount of coordination is necessary between local community members, particularly fishermen and oyster collectors, and local forestry officials is required to establish and maintain if effective protection.

One of the best ideas that is being implemented to protect the mangroves is establishing bee hives within the mangrove trees allowing the bees to deter harvesting. This is a low-cost, sustainable, and effective solution that provides mutual benefits. The bees and mangroves have a symbiotic relationship where the bees pollinate and protect the mangrove trees and the mangroves provide shelter and nectar for the bees. This relationship promotes the health of the mangroves and likely increases pollination services to local crops and garden plants, which benefits the local communities. Coming up with low-cost solutions such as this are important, especially in developing nations where large-scale and expensive projects are not feasible.
Reforestations in the Saloum Delta

Due to the level of mangrove degradation of many (but not all) areas of the Saloum Delta, it seems that human intervention is required, in the form of mangrove reforestations, to promote and facilitate restoration of the mangrove ecosystem. Interviewee responses involving important factors that determine the success of mangrove reforestations included site selection, propagule quality and scale of the project. Site selection seems to be well-known by participating actors and factors such as soil composition, salinity, and intertidal zones are often considered. The quality of the propagule is also of importance and is simply identified by whether the top of the propagule is attached and if it is green (pink or white indicates a dead propagule). However, what is not often mentioned or considered in the reforestation process is species selection.

All communities involved in the interview process had conducted mangrove reforestations with the genus *Rhizophora*, yet few had conducted reforestations with *Avicennia*, and no communities had reforested with *Conocarpus* or *Laguncularia*. Considering individual values for each of these genera through the interviews and by looking at the correspondence analysis (Figure 11), we can see that *Rhizophora* spp. are associated with and valued for their wood, and provision of habitat and ecosystem services. The other three species, however, are more often associated with and valued for their leaves and seeds. The leaves and seeds of these species are used for food, traditional medicine, dyes, hair products, and animal fodder. These responses suggest that mangrove species provide different services to the communities that use them. Respondents also suggested that the different species filled different spatial niches regarding their distance from the channels edge.
Taking this idea and the current management of mangrove reforestations into consideration, it seems that the need to replace strands of *Rhizophora spp.* is being met. However, there is a huge lack in effort to reforest lesser known mangrove species. This fact is in no doubt due to the lack of knowledge regarding the factors that contribute to successful reforestations with these species combined with the complicated process that is required to reforest with *Avicennia*. According to respondents who attempted to reforest with *Avicennia*, the demanding process often results in low survival rates (below 40%). The process typically involves the establishment of a nursery using plastic tree sacks placed in buckets that allow the salt water to enter with the daily rising of tides. A fence is also required to keep out crabs that would harm the propagules. Expertise and capital are required to establish these nurseries and later conduct the out planting, which most communities do not have available. In fact, some organizations discouraged communities from reforesting with *Avicennia* due to the complicated process involved. In the wild, most *Avicennia* propagules only grow well underneath the mother tree and must be planted on the bank of the river often nearer to human pressures. The fact that *Avicennia* roots do not allow for oyster development or protection of small fishes does not encourage people to plant this species.

No reforestations of *Conocarpus* or *Laguncularia* were known of or had been attempted by local communities or organizations. This could result from several factors. One could be that the low relative abundance of these species make them difficult to locate. Another factor may be that these species are not as valued or prioritized. Many people may not even be aware that they are mangrove species and are decreasing in number. It is also possible that no one has tried or would know how to conduct a reforestation with either of these species. Even if it has been attempted, it may be more difficult than the process of replanting *Avicennia*.  

71
The fact that only *Rhizophora* spp. are being utilized in reforestations presents several complications with regards to mangrove restorations. For one, the mangrove ecosystem is not being restored to its previous state as there is what is perceived as a gradual loss of *Avicennia*, *Conocarpus*, and *Laguncularia* combined with a high rise in *Rhizophora* spp. abundance. The promotion of mono-specific strands causes a reduction in mangrove species diversity because it lowers species evenness and may eventually lower species richness and result in the local extinction of the less abundant species. A decrease in species diversity could destabilize the mangrove ecosystem. For example, the reliance on primarily a single genus could render a mangrove forest more susceptible to a devastating insect and pathogen attack, which could have severe consequences including a near total loss of ecosystem services.

To diversify mangroves and increase their resilience, efforts should be made to increase the quantity and quality of *Avicennia*, *Laguncularia*, and *Conocarpus* spp. Future research should be focus on developing methods of seedling development and transplantation associated with successful reforestations. The research could be done by conducting field observations and/or setting up controlled experiments in a field or laboratory setting. Parties conducting mangrove reforestations also need to consider what species is most appropriate when considering the site selection. Since lesser-known species occupy a different spatial niche than *Rhizophora* spp., it may be more appropriate to plant a strand of *Avicennia*, *Conocarpus*, or *Laguncularia* in certain areas. Planting *Rhizophora* spp. propagules next to already existent trees of lesser-known genera should also be avoided as they could often outcompete species from other genera.

Other studies have also noted that the hydrology of various waterways plays in restoring a mangrove ecosystem (Bosire 2008; Wolanski et al. 1992). Respondents never mentioned that this factor was considered when conducting reforestations, especially during the site selection.
process. It might be that the actors involved in Senegal may not have access to the technical knowledge or resources required to assess hydrology, as indeed this is a developing field of research in mangrove studies across the globe (Bosire 2008; Wolanski et al. 1992).

**Coordination among stakeholders**

When considering management of the mangrove ecosystem it is important to think about the goals of the local communities and associated outside organizations. For the local communities, their interests lie in managing the mangrove ecosystem in a way that allows them to sustainably harvest the resources the mangroves provide, upon which they rely. Because I did not focus on the values or perspectives of outside organizations and actors, I cannot speculate as to what those might be. However, it should be noted that during the interviews, I was a volunteer for an American government organization and conducted mangrove reforestations and education efforts in coordination with local communities and NGOs. In my experience, the general mood of local communities regarding outside organizations participation in mangrove management seemed to be positive. Outside organizations often possess much needed technical expertise and knowledge that they can share with local communities in the ways of conducting mangrove reforestations. Some organizations can also provide capital for purchasing the resources necessary for proper management, help conduct larger-scale projects, or help mitigate financial loss associated with taking time off to conduct mangrove reforestations. However, based upon interviewee responses, it seemed to me that outside organization involvement could be improved.

In all instances, management decisions should be made to promote a high level of community involvement and should reflect the goals of the community in the interest of
cooperation, productivity, and respect. Community members should be involved in, and trained on the site selection process, and their expertise should be always be considered because they are the most familiar with those areas. Species selection should also become a regular step in the mangrove reforestation process. Outside organizations stand the best chance of acquiring technical knowledge and expertise to ensure the success of reforestations with lesser known species. As such, they should work these lesser known species into the curricula used for awareness trainings and sensitizations, and resources should be made available to local communities should they choose to reforest with a species other than those of *Rhizophora*.

However, this knowledge and expertise could be shifted to local community members by funding research opportunities at local research and higher-education institutions to encourage local community members to take initiative in developing solutions to issues associated with natural resource management.

It is noteworthy that some organizations working in Senegal do so for the benefit of receiving carbon credits. Carbon credits are financial instruments awarded to countries or groups that emit greenhouse gases below their emission quota (Investopedia.com). Carbon credits can be traded and purchased on the international market and allow a country or group to emit one ton of carbon dioxide (i.e. it allows a receiver to emit an amount of hydrocarbon fuel over a period of time (Investopedia.com)). This system was established by the International Panel on Climate Change (IPCC) in conjunction with the Kyoto Protocol and is meant to offset carbon emissions. For example, Oceanium’s “Plant your tree” program is registered with the United Nations Framework Conventions on Climate Change and is sponsored by Danone at four million euros (Salem and Panfili 2016). However, Danone chose not to continue this program because of its low success rate in terms of carbon sequestration.
Carbon credits have actual market value and can be collected by organizations conducting reforestation projects. Thus, it may be in an organization’s best interest to conduct projects on as large a scale as possible. Many respondents noted that some reforestations were conducted at unnecessarily large scales and in areas where propagule survival was highly unlikely. In projects that span large areas, it is easier to plant *Rhizophora* spp. propagules.

Some respondents also noted that there was little follow up to these projects and in some cases the organization’s representatives never returned to check on the success of the project. This process of conducting large scale reforestations with only *Rhizophora* spp. propagules, a process that has been termed “green grabbing” (Fairhead et al. 2013), may not be conducive to the goals of local communities and it is possible that these projects could do more harm than good in the long-term. It is very difficult to judge how these projects will impact biological diversity and ecosystem functioning compared to natural regeneration because there are little available quantitative data pre- and post reforestations (Salem and Palini 2016).

One recent study has claimed that carbon sequestration is merely an excuse

“(i) to disempower the local communities and to have power over them (the coinciding reforestation and election campaigns in 2012 testify to such political diversions and instrumentalisation), and (ii) to empower private enterprises for the purchase of carbon offsets. REDD+ initiatives opened up opportunities for “mangrove grabbing”’ (Salem and Palini 2016).

The concept of mangrove grabbing refers to “the dispossession or appropriation of use or control of, or access to, mangrove resources and lands by traditional users, territorial use rights holders and inhabitants” (Salem and Palini 2016). Since the Saloum Delta is public land it belongs to the communities that live there. However, the authors suggest that reforestation programs are being
used to take control and access to these lands away from the local communities (Salem and Palini 2016). With what seems to be many outside actors conducting reforestations on a large spatial scale that do not align with necessary restoration measures and lack follow up on the biological and socioeconomic impacts of those reforestations, local management authorities should monitor and regulate outside actor involvement in mangrove ecosystem management. When it comes to development and conservation projects, community-based natural resource management should be given higher priority.
LIMITATIONS AND FUTURE STUDIES

When living and conducting research in Senegal, one must be very adaptable and ready to deal with complications. However, these opportunities often led to delightful conservations and interesting situations. This study was mainly limited in scope due to available time and resources. I conducted this research while serving as a United States Peace Corps Volunteer and therefore had responsibilities that needed to co-exist with my research. Since snowball sampling was used, the interviews may have only revealed a narrow range of perceptions. Random sampling may have yielded different results, however, this study wished to focus on members local communities who were directly involved with mangrove management decisions. I would have liked to meet with NGOs to discuss their perceptions, however, many of them are located in the capital, Dakar, and I had limited opportunities to visit this city.

Since the interviews were being translated from French or Wolof to English, it is possible that some ideas were lost in the translation. Sometimes the interviewee, translator, and I would have to give many examples to identify the meaning of a word. I made every attempt to construct interview questions so they would not be leading or biased. Although this was communicated to the translator, sometimes, due to the limitations of the Wolof language, it was very difficult not to include words that could be construed as leading. For example, the translator and I tried to find ways to not involve the word “njerin”, which directly translates to “importance.” I noticed this word was being used for questions dealing with interviewee perceptions of mangroves and their effects on communities and the environment. Often, respondents would be confused about the direct translation of the question, and so the translator would offer the question: What is its importance? This tells the interviewee that they should consider the mangrove to be important and may have introduced bias into responses. After
interviews were conducted, translator and I would discuss complications and solutions to these issues to mitigate the situation in future interviews and reduce bias.

A series of sample mangrove photos were used by the research team to generate responses regarding mangrove genera (Appendix). However, some respondents were unable to identify different mangroves in the pictures. Some respondents also believed that the researchers were asking questions about a particular tree being shown in the photo instead of the group of that type of tree as a whole. It was evident that a few respondents offered answers even though they appeared to be uncertain about what they were talking about. A couple respondents also seemed to be in a hurry and may have given answers in a manner that would get them through the interview as quickly as possible.

It appears that quantitative data of the abundance and cover of individual mangrove species in the Saloum Delta and their change over time is not readily available. These data would be highly beneficial to managers of the mangrove ecosystems. Surveys of mangroves and associated biota should be conducted on a more regular basis so that researchers may have a good perspective on the situation of the Saloum Delta.

Future research needs to be conducted on the factors that promote and limit mangrove health and growth. If lesser-known species, such as those previously discussed, are to be used in reforestations, then there needs to be new studies on what can be done to raise success rates, both when establishing a nursery and out planting at the reforestation site. Studying the hydrology of associated waterways and its effect on mangrove forests is also a research field of growing interest. There has also been a call to use methods that consider all the services and values mangroves provide, and not just to consider them in the context of carbon sequestration (Salem and Panfili 2016).
It should be noted that several respondents mentioned that similar interviews as this one had been conducted. They stated that many researchers come to their communities but do not return or present the findings to the villages. Ideally, researchers would return to participating communities and present the results and findings. Unfortunately, this is not always feasible, especially in a Peace Corps Masters International program. However, more effort should be made by the researchers, including myself, to communicate the findings to their participants. The respondents have been gracious enough to share their time and stories and researchers should work hard to share their knowledge. It may be as simple as sending a summary of results by mail to a collaborator living near the communities that would be able to explain the results to the community. Also, researchers and organizations involved in reforestation projects should try and return to the project site to follow up on the success of the project and have a discussion with the associated community so that information leading to more successful future projects may be collected.
CONCLUSIONS

The scientific community has a long way to go to fully understand the complexity of mangrove ecosystems and as such further research is necessary. When conducting studies, it is important to consider all the resources, services, and values mangrove provide the local communities that rely upon them. Mangrove species occupy different niches in the natural and anthropogenic realms indicating that future research is needed on how we can prevent the loss of these species and what factors can increase the likelihood of success in reforestations involving lesser-known mangrove species. As of now, little is known of the effect mangrove reforestations have on biological and socio-cultural diversity. However, it seems that many reforestation projects are being conducted by outside organizations at large spatial scales, and it is not certain if the appropriate attention is being made to study the potential impacts. If this pattern is to continue, there could be negative implications in the long term, including cryptic degradation and decreased species diversity, which would be highly detrimental to the local communities that are trying to live sustainably amongst these ecosystems, as well to the economy of Senegal.

When it comes to development and conservation projects, I believe too many organizations are conducting large-scale, expensive projects that often draw popular media attention but are ultimately unsustainable and even detrimental to local communities and ecosystems. As has been discussed, the goals of these outside actors do not necessarily reflect the goals of local communities. Incentives including the collection of carbon credits under the REDD+ initiative may also be contributing to unsustainable projects that do not promote biological and socio-economic diversity.

Therefore, community-based natural resource management should be the main strategy implemented with regards to mangrove ecosystems. This would promote sustainable, long-term
methods, shift the power of management decisions to local communities, and increase local community investment in a project. With a continuation of education and awareness raising campaigns, and with special attention to the ecosystem services mangroves provide, local communities would possess the knowledge required to take control of local management decisions. The Wolof proverb “Ndimal na fekk ci loxoy borom” comes to mind, meaning “Help is in one’s own hands.” These communities are aware of the values and importance that mangroves possess and are willing to work to protect their interests. They deserve the chance to do so.
Literature Cited


Appendix
**Rhizophora mangle**

Wolof: mang
Sereer: njas
Soce: manco
Rhizophora mangle
Wolof: mang
Sereer: njas
Soce: manco
Avicennia germanins
Sereer: mbugand
Soce: dubokhun
Avicennia germanins
Sereer: mbugand
Soce: dubokhun
Conocarpus erectus
Sereer: niara/ndamb/ndaram/ndam gere
Soce: manco cena
Conocarpus erectus
Sereer: niara/ndamb/ndaram/ndam gere
Soce: manco cena
Laguncularia racemose
Sereer: njas fall/njas bak
Soce: cacharolen/manco cena
Laguncularia racemose
Sereer: njas fall/njas bak
Soce: cachá rolen/manco cena
Perceptions of mangrove species: A case study of the Saloum Delta, Senegal

Interview Script

1. Asalam malekum. Can you please tell me your name and what you do for work?

2. How do you feel about the current status of mangroves in the Saloum delta?
   a. How do you feel about the amount of mangrove species richness?
   b. How do you feel about the amount of mangrove species eveness?
   c. How do mangroves affect you?
   d. How do you feel about the affect mangroves have on the environment?
   e. How have you learned about mangroves?
   f. What do you think about mangrove reforestations?

3. What do you think about Rhizophora mangle (/Languncularia racemosa/R. racemosa/R. harrisonii/Conocarpus erectus/Achrostichum aureum) mangroves?
   a. How do you feel about its relative abundance?
   b. With regards to your community?
      i. How do you feel about the harvesting of this species?
   c. With regards to the environment?
      i. How do you feel about the species diversity within strands of [mangrove species]?
   d. With regards to the protection of this species?
   e. With regards to reforestations?
      i. How do you feel about the site selection?
      ii. How do you feel about the survival of the propagules?
      iii. How do you feel about the follow-up after the reforesting?
      iv. How do you feel about their overall success?

4. Is there anything else you wish to mention? Do you have any questions for me?

5. Thank you very much for your time and input.