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Quantification of the impacts of water hyacinth on riparian communities in Cameroon and assessment of an appropriate method of control : the case of the Wouri River Basin

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QUANTIFICATION OF THE IMPACTS OF WATER HYACINTH ON RIPARIAN COMMUNITIES IN CAMEROON AND ASSESSMENT OF AN APPROPRIATE METHOD OF CONTROL

The Case of the Wouri River Basin

By

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Cameroon

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The content of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Quantification of the impacts of Water Hyacinth on riparian communities in Cameroon and assessment of an appropriate method of control**: **The case of the River Wouri Basin.**

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Some plants, when transported to non-endemic areas undergo reproduction and rapid growth and will out-compete native plants and become weeds. These weeds then become troublesome giving rise to socioeconomic and environmental impacts. Water hyacinth (*Eicchornia crassipes*), one of such weeds is often considered the world's worst invasive aquatic species of weed, indigenous to the Amazon Basin of South America and has spread over the years to various areas in Africa and Asia.

This dissertation analyses the problem of water hyacinth infestation in the Wouri River Basin, done through the quantification of its socio-economic and environmental impacts on riparian communities. It aims at providing information to decision-makers and other stakeholders to assist them invest in projects geared towards preventing its spread thereby reducing the impacts on the riparian communities.

The riparian communities are identified and data on the socioeconomic and environmental impacts of water hyacinth are collected through focus group discussions and interviews. The data are then presented and analysed.

Furthermore, the various available methods of control are examined taking into account the benefits and setbacks of each method. Finally, a suitable strategy for the control of water hyacinth in the Wouri River Basin is proposed. The method shows that the total lost benefits of the communities due to water hyacinth infestations, outweigh the cost of implementing the appropriate control measures; hence justifies the need for urgent measures to be taken to manage water hyacinth in the Wouri River Basin.

Key words: Water hyacinth, quantification, control, impacts, riparian communities, aquatic weed, invasive species.

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ADF:	African Development Fund
BRN :	Burma River Network
BUCREP:	Bureau Central des Recensements et des Etudes de Population (Central Bureau of Census and Population Studies)
CABI:	Centre for Agriculture and Biosciences International
CIA:	Central Intelligence Agency
CNIC:	Chantier Naval et Industriel du Cameroun
CRD :	Capital Regional District
CRD:	Capital Regional District
CSC:	Commonwealth Science Council
CSIRO:	Commonwealth Science and Industrial Organization
CUD :	Communauté Urbaine de Douala (Douala City Council)
CWPT:	Civil War Preservation Trust
DAMVN:	Direction des Affaires Maritimes et des Voies Navigables (Department of Maritime Affairs and Inland Waterways)
DPIPWE:	Department of Primary Industries, Parks, Water and Environment
EBI:	Encyclopedia Britanica Incorporation
ECOWAS:	Economic Community of West African States

FAO/ACPD:	Food and Agricultural Organization/ Agriculture and Consumer Protection Department
FCO:	Foreign and Commonwealth Office
GCI:	Global Conscience Initiative
GIS:	Geographic Information System
GISD:	Global Invasive Species Database
GISP:	Global Invasive Species Programme
GNI:	Gross National Income
GPS:	Global Positioning System
IITA:	International Institute for Tropical Agriculture
IRDC :	International Research Development Centre
ISSG :	Invasive Species Specialist Group
IUCN:	International Union for the Conservation of Nature
MINEPAT:	Ministère de l'Economie, de la Plannification et de l'Amélioration du Territoire (Ministry of Economic Planning and Regional Development)
MINEPIA :	Ministère de la Pêche de l'Industrie Animale (Ministry of Fisheries and Animal Husbandry)
MINFOF :	Ministère de la Forêt et de la Faune (Ministry of Forestry and Wildlife)
MINRESI:	Ministry of Scientific Research
MINT:	Ministry of Transport
NAS:	National Academy of Sciences
NOAA:	National Oceanic and Atmospheric Administration
PIA:	Primary Industries Agriculture
PLaW:	People's Land and Water Initiative
SDV:	Société Delmas Vieljieux
UF/IFAS:	University of Florida/ Institute of Food and Agricultural Sciences
UIC:	Union Industrielle du Cameroun
US/EPA:	United States Environmental Protection Agency
USDA:	United States Department of Agriculture
UZJ:	University of Witswatersrand Johannesburg
WHIP:	Water Hyacinth Information Partnership
WSDE:	Washington State Department of Ecology
WTG:	Watershed Task Group
WWF:	World Wildlife Fund

Chapter one

Introduction

Oceans, seas, rivers, lakes and estuaries are among the wide variety of aquatic habitats found on earth, with oceans and major seas covering more than 70% of the earth's surface (De Poorter, Darby & MacKay, n.d.). These habitats are biologically very productive; hence, people derive various benefits from them for their livelihood. They provide various types of fish on which more than one billion people rely as their main or only source of animal protein (De Poorter et al, n.d.). They are equally favourable sites for recreational activities, tourism and research.

However, over the years these aquatic habitats have been under threat from human activities such as pollution, over exploitation, habitat destruction, conflict of uses and natural phenomena such as climate change. One of the most treacherous is threat from alien invasive species of micro-organisms, plants and animals. Aquatic organisms evolve in isolation in their environments, separated by natural barriers, which have been overcome by humans, through shipping, travel by air and other means of transport (De Poorter et al, n.d.).

Plants in particular, play an important role as members of the aquatic environment by providing food and shelter for other plants and animals. Some plants, when transported to non-endemic areas will undergo rapid growth to out-compete native plants and become weeds. These weeds then become troublesome and cause environmental and socio-economic problems (Mailu, 2001). The water hyacinth plant, one of such weeds is considered by many to be one of the world's worst invasive aquatic species of weed, indigenous to the Amazon Basin of South America (GISD, 2006). It was cultivated as a greenhouse and landscape exotic plant shortly after the Civil war (Penfound & Earle, 1948), which took place from 1861 to 1865 (CWPT, 2011). However, the first authentic account details its introduction as an ornamental plant in the United States in 1884 at the Cotton Centennial Exposition in New Orleans, Louisiana (Gopal & Sharma, 1981). It was similarly introduced in many parts of the world as an ornamental plant and today it is found in more than 50

countries on five continents (GISD, 2006; Lowe, Brown, Boudjelas & De Poorter, 2000). In the last two centuries, it has spread throughout the tropics and has become one of the major problems in water bodies of the tropics and sub-tropics.

Water hyacinth is a free-floating perennial, herbaceous, aquatic macrophyte that invades fresh water rivers and lakes and grows rapidly, forming expansive colonies of tall interwoven dense floating carpets of plants which often create impenetrable barriers and obstruct navigation (Wise, van Wilgen, Hill, Schulthess, Tweddle, Chabi-Olay & Zimmermann, 2007). It also infests estuaries, wetlands, streams, ponds, waterways as well as eutrophied lakes and river mouth areas (Ndimele, Kumolu-Johnson & Anetekhai, 2011). Its impacts on the riparian communities range from social and economic to environmental impacts (Mailu, 2001) due to its potential to grow rapidly and produce enormous amounts of biomass covering extensive areas of naturally open water (Wittenberg & Cock, 2001).

Water hyacinth is known to have been introduced in Africa in the 1880s (Gopal, 1987) by tourists who were attracted to its brightly coloured purple flower (Figure 1).

Figure 1: The natural beauty of water-hyacinth's flower and foliage that has helped its spread to become a floating nightmare in many tropical areas.
Source: USDA

It was brought to Africa to be used in flower gardens and has spread throughout various regions of Africa and the Middle East. Looking at the attractiveness of the flowers, there is no doubt why Gopal, 1987 described the weed as a "beautiful devil". The first introduction to the African continent was made in Egypt in the late 1880s (Gopal, 1987; Navarro & Phiri, 2000) but the potential problem for water resources

was not described until 1932 (Navarro & Phiri, 2000). In general, Egypt had no problem with water hyacinth before the construction of the Aswan High Dam [from 1960 to 1970 (Biswas, 2002; Clancy, 2009)]. Until then, the annual flood of the Nile had flushed the weed out into the Mediterranean. It became a menace in Egypt around 1975 to 1985 (Navarro & Phiri, 2000). Water hyacinth was first recorded in South Africa on the Cape Flats in 1908 (Stent, 1913 cited in UWJ, 2012) and was introduced into Kwazulu-Natal around 1910 (Edwards & Munsil, 1975). Since then, nutrient-enriched waters have assisted its spread throughout the country (Hill & Cilliers, 1999).

Furthermore, water hyacinth has been present in eastern and southern Africa for more than four decades since it was recorded in Zimbabwe in 1937 (Navarro & Phiri, 2000). It continued to colonize important water bodies in the region, such as the Incomati River in Mozambique in 1946, the Zambezi River and some important rivers in Ethiopia in 1956, rivers in Rwanda and Burundi in the late 1950s (Navarro & Phiri, 2000), the rivers Sigi and Pangani in Tanzania in 1955 and 1959 respectively (Mallya, Mjema & Ndunguru, 2001) and Kafue in Zambia in the 1960s, the Shire River in Malawi in 1968 and Lake Naivasha in Kenya in 1982 – 1983 (Navarro & Phiri, 2000). Most recent records of infestations are from Lakes Kyoga in Uganda in 1988-89, Victoria in 1989–1990, Malawi – Nyasa in 1996 and Tanganyika in 1997 (Navarro & Phiri, 2000).

Water hyacinth was first reported in Cameroon between 1997 and 2000. Since then, wetlands in Cameroon have become “homes” for water hyacinth which has been reported to have colonized rivers Wouri, Nkam and Sanaga in the Littoral region, Nyong in the Centre region, Benoue and Lake Lagdo in the North Region, Lake Maga in the Extreme North region, rivers Sangha, Ngoko, Dja, Boumba in the South and East regions, which form part of the Congo Basin (Forpah, 2009).

In the Wouri River Basin, water hyacinth was sighted around 1997. It has drawn the attention of environmentalists because it has become a menace to communities and biodiversity. Its rapid dissemination in this area is stimulated by the influx of

nutrients from the many industries located around the estuary through run-offs which cause eutrophication and the lack of natural enemies to destroy the weed. Also, the lack of knowledge about the extent of damage to the riparian communities and the cutting and releasing of bunches of water hyacinth into the river by upriver communities has also contributed to its spread. The rich biodiversity of the Wouri River Basin, its social importance acting as a site for cultural manifestations and recreational activities as well as its economic importance acting as a source of income for the local community, all make it very important to the riparian communities. It is therefore important to control the spread of water hyacinth in the short run and subsequently completely eliminating it in the long run.

This research attempts to quantify the socioeconomic and environmental impacts of water hyacinth on riparian communities in the Wouri River Basin and propose an appropriate strategy for its management.

1.1 - Research hypothesis

This research is based on the following postulation:

- The Wouri River Basin is heavily infested by the alien invasive species of weed called water hyacinth.
- The riparian communities derive their livelihood from the resources from the Wouri River Basin.
- Water hyacinth infestation causes social, economic and environmental problems for the riparian communities.
- Lack of knowledge about the extent of the water hyacinth infestation as well as the degree of impacts to the riparian communities has made it difficult to sort for a solution to the problem.
- Institutional, technical and financial problems are the main constrains to the fight against the proliferation of the weed.
- The total lost benefits of the communities due to water hyacinth infestations outweigh the cost of implementing the appropriate control measures.
- Integrated management strategy is the appropriate measure required to reduce the weed to a level which is no more problematic.

1.2 - Statement of the problem

Water hyacinth, since its introduction in Cameroon, has been a menace to the riparian communities, causing several problems. *Inter alia*, it forms dense mats on rivers, lakes and ponds due to its potential to grow rapidly. It hinders boats from sailing hence disturbs boating activities, swimming and causes starvation as inhabitants of riparian communities cannot carry out fishing which is their main source of income and protein. Touristic activities are hindered and transportation of goods through rivers is no longer possible because propellers are hooked by the water hyacinth mats. It suffocates fish and other biodiversity by preventing the penetration of oxygen through its thick mats to the bottom of the water body. It acts as breeding grounds for mosquitoes, snakes, crocodiles and vectors of schistosomiasis thereby causing disease to the communities. Therefore the use of the river by these communities is limited by the knowledge of the presence of these diseases.

Although the range of problems with water hyacinth infestation is in general terms widely known, the real extent of the impacts on the socioeconomic status and welfare of the people who depend on the affected water has not been well quantified and documented. This is one of the most certain explanations for why water hyacinth problem is still poorly understood. However, researchers and experts have realized that this is one of the types of information decision-makers need the most. It is therefore an important knowledge gap that this research is intended to fill.

This study will quantify the impacts of water hyacinth infestations on riparian communities in the Wouri River Basin and provide information to decision-makers who are concerned with the protection of the aquatic environment to make appropriate decisions and invest in various projects aimed at preventing the spread of water hyacinths to other areas. This will therefore reduce the impacts of existing infestations on the riparian communities. Finally, an appropriate strategy for water hyacinth management in the Wouri River Basin will be proposed.

1.3 - Objectives of the study

1.3.1 - General objectives:

1. To provide information to decision-makers on the level of infestation and the extent of impacts of water hyacinth on the riparian communities in the Wouri River Basin.
2. To propose a comprehensive strategy for the management of water hyacinth infestation in the Wouri River Basin.

1.3.2 - Specific objectives:

1. To assess the distribution of water hyacinth in the Wouri River Basin in order to determine the number of hectares covered by water hyacinth as well as the degree of infestation at particular sites;
2. To quantify the socioeconomic and environmental impacts of water hyacinth, in order to determine the extent of impacts on the riparian communities;
3. To assess available methods for control of water hyacinth, in order to identify the appropriate method suited for the management of water hyacinth in the Wouri River Basin.

1.4 - Methodology

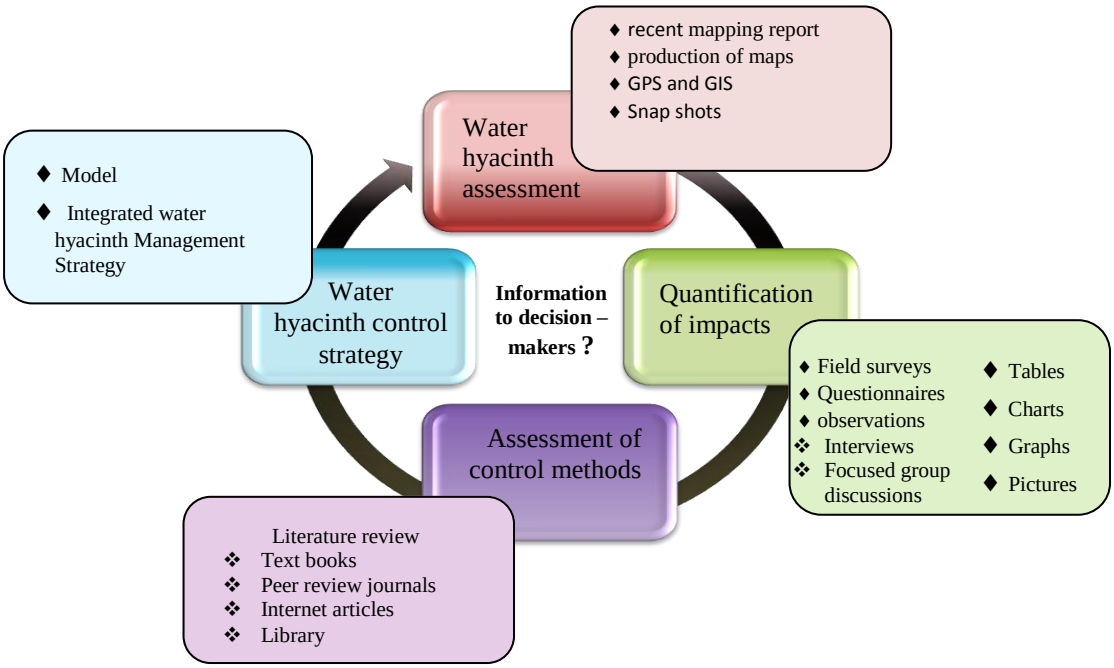


Figure 2: Schematic representation of the selected methodology

Chapter one presents the problem of water hyacinth in the Wouri River Basin, the objectives of the study and examines some literature on what has been done on this issue.

Chapter two and three present the area of study and the water hyacinth plant respectively, with special emphasis on the biology and ecology of water hyacinth, its distribution as well as its impact on riparian communities.

Chapter four quantifies the impacts of water hyacinth on riparian communities. Data collection, presentation and analysis methods were also presented.

Chapter five assesses the various methods available for water hyacinth control and presents a comprehensive strategy for water hyacinth management in the Wouri River Basin.

The last chapter identifies some initiatives that have been established to control water hyacinth at the international, national and local levels and further explains some constraints to the fight against its proliferation in Africa and the Middle East as well as in Cameroon. Some recommendations are equally proposed.

1.5 - Literature review

Several studies have been carried out in the past years in many countries in the world at large and in Africa and Cameroon in particular. Some of these studies will be examined in order to get a broad knowledge of what has already been done in the fight against the proliferation of water hyacinth and areas for further research.

Labradar, (1995) briefly describes the problems caused by water hyacinth in various countries in Africa and Latin America and the actions undertaken by FAO, and other agencies or institutions regarding the implementation of programs for the control of this floating aquatic weed. The constraints posed by all available control methods are also discussed. Labradar emphasized the fact that, under certain circumstances, biological control of the weed alone will not be sufficient to effectively reduce the plant in a reasonable period of time. Therefore, an integrated approach for the control of the weed is recommended which may consist of mechanical and/or systematic manual removal, and the use of herbicides in particularly infested sites. Each method

has its own economic and environmental constraints, and practical advice is needed in choosing the short-term methods to complement the effect of biological control.

Similarly, Pieterse, Mangane, Traoré, van de Klashorst and van Rijn, (1995) explained that water hyacinth was first observed in West Africa in the late 1970s. Although the harmful effects of water hyacinth are generally known, it seems impossible to stop its further spread. Due to the need to control the weed in the West African region, the Economic Community of West African States (ECOWAS) was funded to carry out a study on the current state of affairs. The distribution of the plant in countries in West Africa and various methods of control were described as well as some proposed follow-up projects by ECOWAS to control water hyacinth in West Africa.

Furthermore, Neuenschwander, Ajuonu and Schade, (2001) explained that water hyacinth, was first reported in Benin in 1977 and about 10 years later occurred as a major floating water weed in the southeast, obstructing boat traffic and fisheries. Further, the success of biological methods to control was appreciated in this area when two weevil types; *Neochetina eichhorniae* and *Neochetina bruchi* were released. The weevils had a positive impact on the water hyacinth. However, they found out that establishment of some species of weevils such as *S. albiguttalis* still shows no evidence of establishment up to twenty months after the first release.

On the other hand, Mallya et al., (2001) advocated for Integrated Weed Management (IWM) strategies for the control of water hyacinth, which according to them, have had significant impact on water hyacinth control in Tanzania. Furthermore, they explained that water hyacinth has been reduced by over 70% within a period of 3 years and this was achieved mainly through biological control, manual removal, quarantine regulations and management of nutrient enrichment. Through manual removal, 60 landing beaches in Lake Victoria were kept free of water hyacinth. Through biological control, two weevils, *Neochetina eichhorniae* and *Neochetina bruchi*, were used which reduced the water hyacinth plant population density from 45 to 7 plants per $0.5m^2$.

Jones, (2000) stated that Water hyacinth was first recorded in South Africa in the Cape Province of Kwa Zulu-Natal in 1910. It is believed to have been introduced as an ornamental aquatic plant and has spread to numerous localities throughout the country by gardeners, aquarium owners and boat enthusiasts. The article reported the success of integrated approach to water hyacinth control which cleared a total of 18.9 km of the river between 1995 and 2000 through the combined use of chemical, mechanical and biological control methods. Reports from the local rural communities that rely on fish as a source of food indicated that their catches have improved which is a sign that the control of water hyacinth in the system is having a positive ecological impact.

Mailu, (2001) presents preliminary data collected in an assessment of the impacts of water hyacinth in the Lake Victoria basin. A summary of the status of control and strategies for the future is given. The report draws on field observations, studies through interviews of affected communities and organisations, personal communications and published reports by scientists in the region. This survey indicates that currently water hyacinth biomass is declining slowly. However, Mailu emphasized the great need to undertake research to quantify the levels of damage, the cost of control, loss of livelihoods, disease, and disruption of normal operations caused by water hyacinth. He further recommended that a common approach needs to be implemented to the management of water hyacinth in order to enhance understanding and alleviate some of the impacts associated with its infestation.

Wise et al, (2007) provides case studies of the economic impact of five invasive alien species in different areas in Africa. The aim of their work was to provide detailed information to administrators and managers. The report gives an overview of water hyacinth and provides an overview of the approach to the economic assessments of its impacts. It also presents data collected as well as findings. The authors further recommends that if control and prevention programmes are to be effective in Africa, it will be necessary to bring the results of studies such as this one to the attention of such bodies, who encourage the spread of invasive species for well-intended

purposes, so that they may better assist with the effective implementation and control policies and projects.

Furthermore, Opande, Onyango and Wagai, (2004) stated that the real source of water hyacinth in lake Victoria was through the Kagera River in Rwanda. This study was to find out the effects of water hyacinth coverage on the livelihood of the lakeshore community. Findings were done through survey and the result showed that the weed is nomadic and impacted the lives of the community both positively and negatively. However, the need for the quantification of the impacts of water hyacinth on the life of the lakeshore communities in the Winam Gulf was deemed necessary in order to establish whether this weed is an enemy or a friend of the lakeshore communities.

Ndimele *et al*, (2011) present water hyacinth control in a different dimension. The authors stated that although water hyacinth has been described as the most troublesome weed in the world, recent studies have shown that it has diverse uses. They further recommended that the potential of this macrophyte should be fully harnessed, which could change its status from a weed to an income-generating plant.

In the same light, Ndimele and Jimoh, (2011) carried out a study between April, 2007 and March 2008 to ascertain the use of water hyacinth as a phytoremediant. The study showed that water hyacinth can accumulate heavy metals even when the concentrations of the metals in the abiotic components (water and sediment) of the aquatic environment is low, suggesting that *E. crassipes* can be used in phytoremediation of heavy metal in polluted aquatic ecosystems.

Chapter two

Area of study

2.1 - The Republic of Cameroon

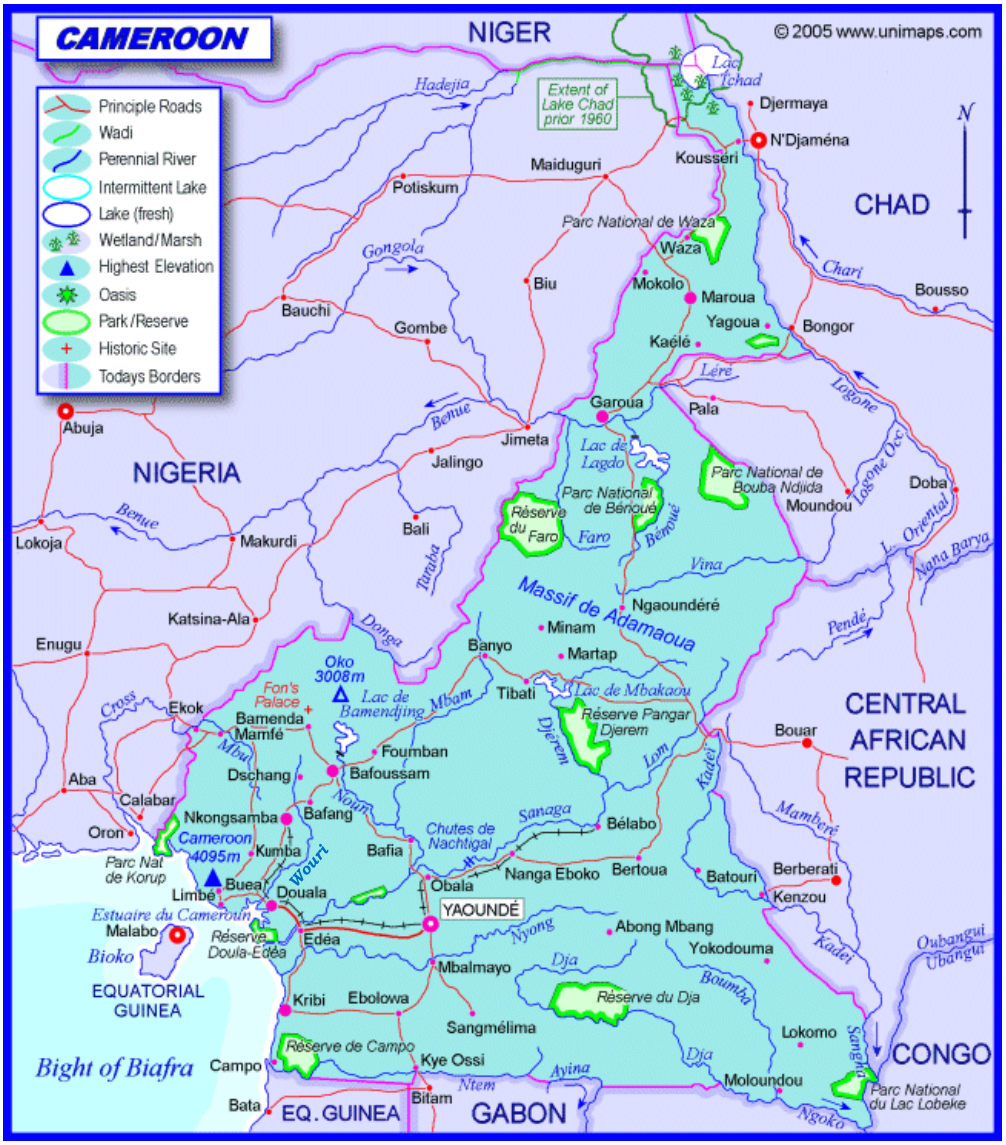


Figure 3: Map of the Republic of Cameroon
Source: http://unimaps.com/cameroon/index.html

Cameroon got its name in the 15th century when the Portuguese explorer, Fernando Poo, first reached the River Wouri estuary in 1472 and because of the presence of giant shrimps in the river at that time, he named it *Rio dos Camaroes* (River of Prawns) whence the name Cameroon is derived (Global Conscience Initiative, 2011).

The Republic of Cameroon is a Central African nation bordering the Bight of Biafra between Equatorial Guinea and Nigeria and located 6 00N and 12 00E. It is bordered by Nigeria to the northwest, Chad to the northeast, Central African Republic to the east, the Republic of Congo to the southeast, Gabon and Equatorial Guinea to the south and the Atlantic ocean to the southwest (Encyclopedia Britanica Incorporation, 2012).

Cameroon has a total surface area of 475,440 km^2, 472,710 km^2 of which is land and 2,730 km^2 is water, giving a land: water percentage of 99:1 (Central Intelligence Agency, 2012). The human population is made up of 20,129,878 inhabitants (July 2012 estimate) with 58% of the population being the urban population and a growth rate of 2.082% (CIA, 2012). The major cities are Yaoundé (capital) with a population of 1.739 million inhabitants and Douala (economic capital) with a population of 2.053 million inhabitants (2009 estimate) (CIA, 2012). The coastline of Cameroon is 402 km (CIA, 2012). As at 2009, the Gross National Income (GNI) per capita is US$1,160 (EBI, 2012).

The rivers of Cameroon form four large drainage systems. In the south the Sanaga, Wouri, Nyong and Ntem rivers drain into the Atlantic Ocean, the Benue River and its tributary, the Kébi, flow into the Niger River Basin of Nigeria, the Lagone and Chari rivers, which form part of the eastern border with Chad, drain into Lake Chad, whereas the Dja river joins the Sangha river and flows into the Congo River Basin (EBI, 2012). Cameroon is often called "Africa in miniature" because of its geographical, climatic and cultural diversity (Forpah, 2004)

2.2 - The River Wouri Estuary

Estuaries or deltas and the lands surrounding them are places of transition from land to sea, and from freshwater to saltwater (United States Environmental Protection Agency, 2009). They are ofte|n peaceful, beautiful landscapes that have attracted artists, canoeists, bird/wildlife watchers, hunters, fishermen, photographers, scientists and teachers (Capital Regional District, 2012). Although influenced by the tides, estuaries are protected from the full force of ocean waves, winds, and storms by the

reefs, barrier islands, or fingers of land, mud, or sand that surround them (US/EPA, 2009). They are one of the most biologically productive types of ecosystems on earth (Burma River Network, 2012), and also one of the most valuable (CRD, 2012).

The sheltered tidal waters of estuaries support unique communities of plants and animals which are specially adapted for life at the margin of the sea. A wide range of habitat types is found in and around estuaries. These include beaches and dunes, rocky foreshores, marshes and other wetlands, mud and sand flats, sea grass meadows, kelp forests and rocky reefs (DPIWE, 2012).

Estuarine ecosystems are essential for the survival of many birds, fishes and mammals and have therefore been referred to as the "nurseries of the sea", as they provide many species of fish with sheltered waters for spawning and safe habitat for juveniles to develop. Many commercially valuable fish species depend on estuaries during some part of their life cycles. Some migratory water birds rely on estuaries as resting and feeding grounds during their migrations (DPIWE, 2012).

People derive recreational, economic and cultural benefits from estuaries. Boating, fishing, swimming and bird watching are just a few of the many recreational pursuits people enjoy in and around estuaries. Estuaries are often cultural and historical centres for coastal communities, serving as focal points for celebrations, customs and heritage. Estuaries are extremely important both ecologically and for human settlements. Of the 32 largest cities in the world, 22 are located on estuaries (NOAA, 2012). Estuaries are an irreplaceable natural resource that requires careful management (DPIWE, 2012).

In Cameroon, the River Wouri estuary is equally very important to the communities living around it. The Wouri River streams in south-western Cameroon at whose middle is located the city of Douala, harbouring the country’s major industrial centres and ports. Two head streams, the Nkam and the Mokombé, join to form the Wouri, 20 miles (32 km) northeast of Yabassi (EBI, 2012). The river then flows in a south westerly direction for about 100 miles (160 km) to empty into the Gulf of

Guinea through the river Wouri estuary. It is navigable for 40 miles (64 km) along its lower course, below Yabassi (EBI, 2012).

The Wouri River Basin is generally rich and harbours a lot of fish and crustacean species, some sea mammals and several species of plankton. The basin is covered by mangrove forests which are under high human pressure due to intensive logging. In the adjacent urban areas like Douala the increasing populations has brought the estimated total number of active loggers to 350 (Atheull, Din, Longonje, Koedam & Dahdouh-Guebas, 2009). The mangroves act as habitat for a variety of commercial fish and shell fish species that breed, spawn, hatch or develop in the mangroves (Atheull *et al*, 2009). Mangroves also protect the coast from the fury of cyclones, floods, sea level rise, wave action and coastal erosion (Kathiresan, n.d.).

Inhabitants of Cameroon's major coastal cities situated around the Wouri River Basin, receive many direct economic benefits from this area. Tourism, fisheries, aquaculture, logging of mangroves and other commercial activities thrive on the natural resources supplied by the basin. Its protected coastal waters also support important public infrastructure, providing ports and harbours vital for shipping, transportation and industries.

Every year, during the first weekend of the month of December, foreigners join the five tribes constituting the Sawa clan in Douala to gather around the Wouri River to celebrate "Myengu", the gods of the waters, thanking them for their protection during the year. The two days festival known as the "Ngondo festival" begins on Saturday, with exciting activities such as Miss Ngondo competition, wrestling and dance conquest of different Sawa dance groups. The main event of the festival takes place on Sunday morning where a spiritualist is immersed with a sacred pot under the river with gifts for "Myengu". After 10 minutes underneath the water, he is expected to return with a message from *Myengu* to Sawa people for the next year. When the pot is brought back to the surface, it is not wet and contains the message from the ancestors, which the spiritualist decodes before announcing it to the waiting crowd. Furthermore, a canoe race performed by the best riders from each Sawa tribe

is equally organized. Over the years, the Ngondo festival has proven to be the best display of culture in the River Wouri in Cameroon (Fri, 2010).

It is therefore evident, that the fundamental importance of the Wouri River Basin to Cameroonians in general and the riparian communities in particular, from a social, economic and environmental perspective cannot be overemphasized.

2.3 - The riparian communities

According to 2010 statistics, the Littoral region of Cameroon is home to 2,865,795 inhabitants constituting 14.8% of the total population of Cameroon, with a population density of 141,5 inhabitants per km^2 (BUCREP, 2010). The region is made up of four divisions namely; Moungo (with 11 sub-divisions), Nkam (with 4 sub-divisions), Sanaga maritime (with 8 sub-divisions) and Wouri (with 6 sub-divisions) (BUCREP, 2010). The Riparian communities that live and derive direct benefits from the Wouri River Basin include villages in the Abo and Dibombari sub-divisions (Moungo division), Yabassi sub-division (Nkam division) and Douala I, Douala IV and Douala V sub-divisions (Wouri division). Generally, a total of about 873,017 inhabitants rely on the Wouri River Basin for their livelihood (BUCREP, 2010). The villages in the Wouri River Basin include, *inter alia*, Sodiko, Pillar, Tonde, Djebale, Lobe, Bonamatoumbe, Mbangue, Bonaloka, Bonamouang, Yassem, Bonangando and Yabea (Figure 4). These communities depend on the fresh water resources of the river for their livelihood and this is contributing significantly to alleviating poverty among them. Their main economic activities are fishing, farming, transportation, logging of mangroves, hunting, palm wine tapping and sand extraction. Douala, the capital of the Littoral region, is the largest city in Cameroon with a population of 2.05 million (FCO, 2012). The city is located at the mouth of Wouri River and is host to about 60 % of the country's industries (Dieudonné, 2004) and largest port. It is the closest city to the riparian communities where their fish, farm and other produce are sold and in return they buy their basic necessities.

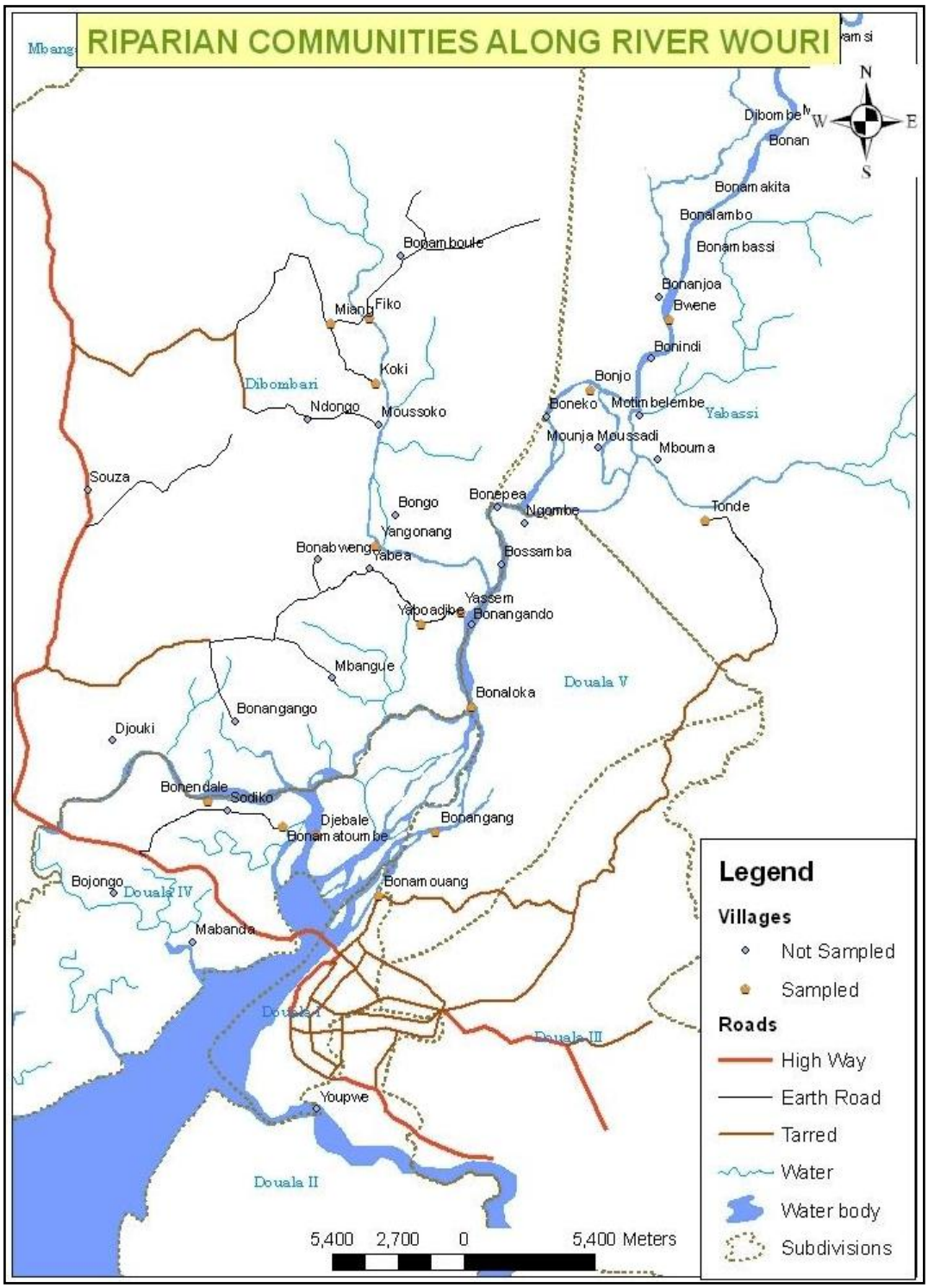


Figure 4: Map of the study area showing the riparian communities in the Wouri River Basin. Produced by Ernest Afangang Ekeocha

Chapter three

The water hyacinth plant

3.1 - Introduction

According to Gopal, 1987, the common name "water hyacinth" arose way back in the 19th Century when Carlos Frederic Philipe Von Martius carried out a four years extensive floristic survey of Brazil from 1817 to 1820. While passing through the Minas Gerais region adjoining the Bahia State, Von Martius collected near Malhada from the pools of stagnant water along the river St. Francisco, an aquatic plant with large swollen petioled leaves and beautiful lilac violet flowers arranged in spikes. Von Martius (1824) named it as *Pontederia crassipes* which was later known as *Eichhornia crassipes*. The flowers resembled those of hyacinth (family: Liliaceae, genus: Hyacinthus) in their beauty so closely that the plant was called water hyacinth.

3.2 - Taxonomy

Eichhornia crassipes is in the Pontederiaceae, a taxonomically problematic family, which has recently been included in the Commelinales (Strange *et al*, 2004). Eight other genera occur in this family of predominantly neotropical, freshwater aquatics, and eight species in the genus *Eichhornia* , all of which originated in South America, except *Eichhornia natans,* which is native to tropical Africa (Gopal, 1987). Only *Eichhornia crassipes* is regarded as a pantropical aquatic weed (Coetzee et al, 2009).

Table 1: Scientific classification of water hyacinth.

Kingdom	**Plantae**	**Plants**
Subkingdom	Tracheobionta	Vascular plants
Division	Magnoliophyta	Flowering plants
Class	Liliopsida	Monocotyledons
Order	Liliales	
Family	Pontederiaceae	Water hyacinth family
Genus	*Eichhornia*	Water hyacinth
Species	*Crassipes*	
Scientific name	*Eichhornia crassipes (Mart.) Solms*	

Source: Samuels, 2009 (www.suite101.com)

The common name of *Eichhornia crassipes* has three spellings namely; « water hyacinth », « waterhyacinth » and « water-hyacinth », but no standardized usage exists anywhere (Coetzee et al, 2009). For the purpose of this dissertation, the name water hyacinth will be used.

3.3 - Morphology

A mature water hyacinth consists of seeds, flowers, leaves, stems (erect stems and stolons) and roots (Figure 5). Seeds are found in capsules which are 1 to 1.5 mm long and roughly egg-shaped, with ridges from end to end. They are long-lived and may survive in mud for up to 20 years. Seeds have also remained viable over very long periods in dry soil (PIA, 2010). The leave stalk is erect, about 50 cm long, spongy, bulbous and carries at the top a single spike of 8-15 conspicuously attractive flowers. The flowers have six petals, purplish blue or lavender to pinkish, the uppermost petal with a yellow, blue-bordered central splotch (Henrylito, 2009).

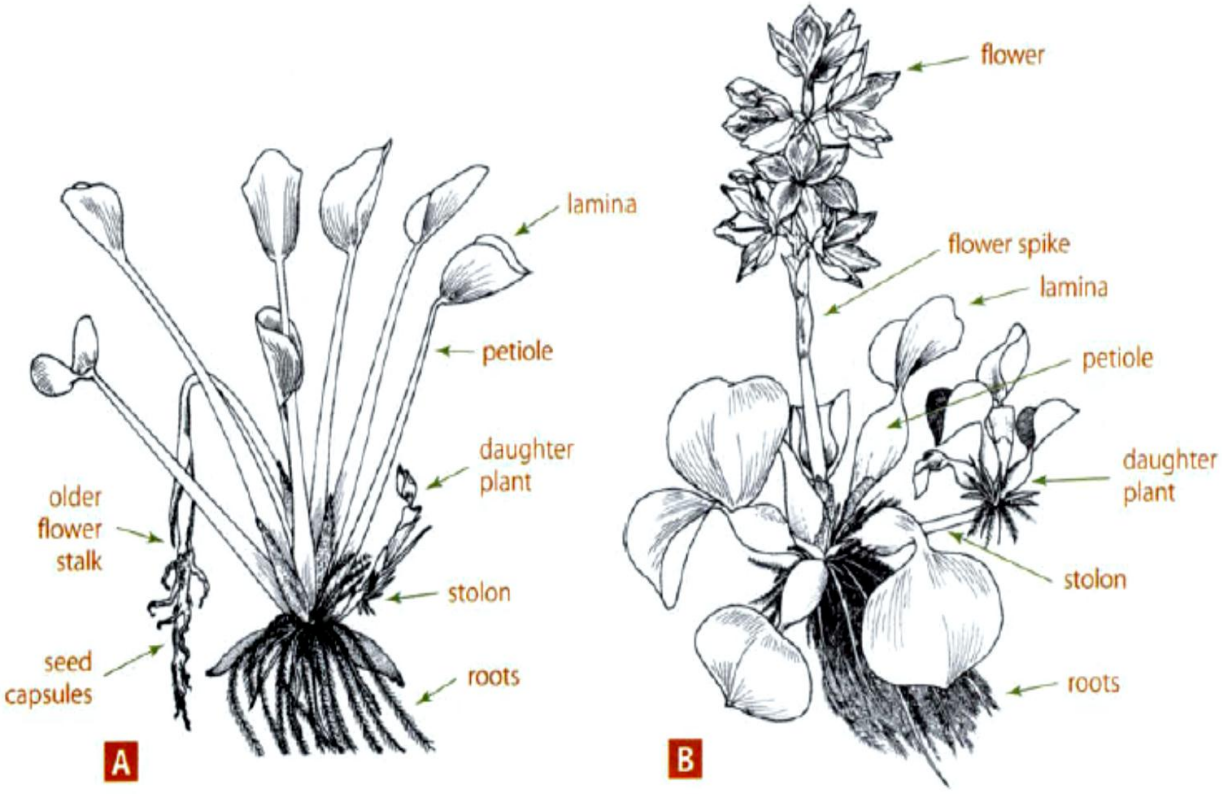


Figure 5: Morphology of water hyacinth plant (A) Slender petioles and (B) bulbous petioles
Source: Wright and Purcell, 1995 cited in Julien *et al*, 1999

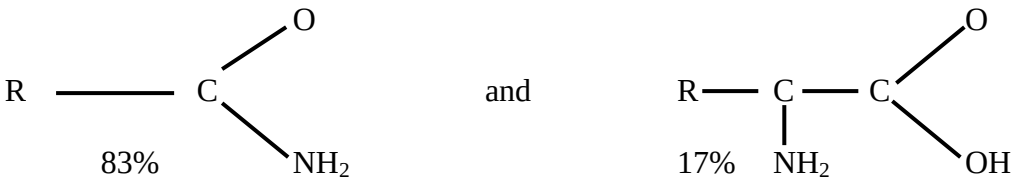
Flowers are of three distinct types, differing in the relative length of styles within single flowers (Barrett, 1977 cited in Julien *et al.*, 1999). Its leaves are broad, thick, waxy, glossy and ovate with circular to kidney-shaped lamina and a thick, spongy, aerenchyma-filled petiole (Julien, Griffiths & Stanley, 2001). It may rise well above the surface of the water as much as one meter in height on stalks. The leaves are 10 - 20 centimetres in diameter with gently incurved, often undulate sides with leaf veins which are dense, numerous, fine and longitudinal. The petioles vary from long and relatively slender to swollen or bulbous. The shape of the petiole influences the amount of air contained and consequently the capacity for the plant to float. Slender petioles are typical of plants that occur within dense, crowded infestations, while bulbous petioles characterise younger plants in open water or on the open-water margins of infestations (Julien *et al*, 2001).

The vegetative stem, 10 cm long and known as stolons consists of an axis with short internodes which produces, at the numerous nodes, all the roots, leaves and new daughter plants at its distal end (PIA, 2010; Penfound & Earle, 1948). The feathery, freely hanging roots are fibrous, unbranched and with a conspicuous root cap (Penfound & Earle, 1948). They are purplish in exposed situations but white when in darkness or when rooted in the soil (Olive, 1894). They vary little in diameter but greatly in length (0.3 ft. to 3.0 ft.) or possibly more (Penfound & Earle, 1948).

3.4 - Chemical composition

Studies have suggested that water hyacinth in its fresh form contains about 90% water and about 15 – 20% solid materials (Ndimele *et al*, 2011). Generally, the dry weight contains about 25 – 35% protein-related matter, with about 17% amino acids and the rest being amides. Amides are usually toxic; reason why water hyacinth is not eaten fresh like other edible vegetables such as lettuce (Ndimele *et al*, 2011). The carbon content of the dry weed is about 36 – 40% (Edewor, 1988) and direct carbonylation obtained 40 to 60% carbonates and nitrates respectively in yield ratios (Edewor, 1988). Therefore, water hyacinth has a predominantly cellulosic structure

highly impregnated by the amino group directly at the carbonyl structure, hence represented as:



Where R could be CH_2 or long chain CH_2-CH_2

Figure 6: Chemical structure of water hyacinth
Source: Ndimele *et al*, 2011

Investigations carried out have revealed R to be more of the aliphatic chain. Therefore, the elemental composition of water hyacinth consists of about 12.8% nitrogen, 36 – 40% carbon, 8% hydrogen and about 13-14% oxygen. It also contains heavy metals such as iron, magnesium and zinc, which justifies its use in phytoremediation (Ndimele, 2003; Ndimele & Jimoh, 2010). Furthermore, Kumar, undated, revealed that long and dwarf type water hyacinth contained 14.28 and 11.87% crude protein, 21.79 and 18.22% crude fibre, 2.01 and 1.18% ether extract, 44.49 and 52.85% Nitrogen Free Extract (NFE) and 17.43 and 15.88% total ash respectively.

3.5 - Biology

Water hyacinth reproduce both by vegetative and sexual reproductive methods and both are characterized by the potential for production of large numbers of individuals in a short period of time (Barrett, 1980b). Seeds are produced in vast quantities, up to 300 seeds per capsule, and are long-lived, remaining viable for 5–20 years (Manson & Manson, 1958; Matthews, 1967; Matthews *et al*., 1977 cited in Gopal, 1987). Seeds sink following release from the seed capsule and may subsequently germinate as water level changes (Wright & Purcell, 1995, cited in Julien *et al*., 2001) (Figure 7). Dispersal of seed is likely to further contribute to the spread of this weed. Seeds are released directly into the water column, from where they can be carried long distances downstream. The numerous and tiny seeds can also be easily transported by vehicles, boats or pedestrians passing through infested areas (Julien *et al*, 2001).

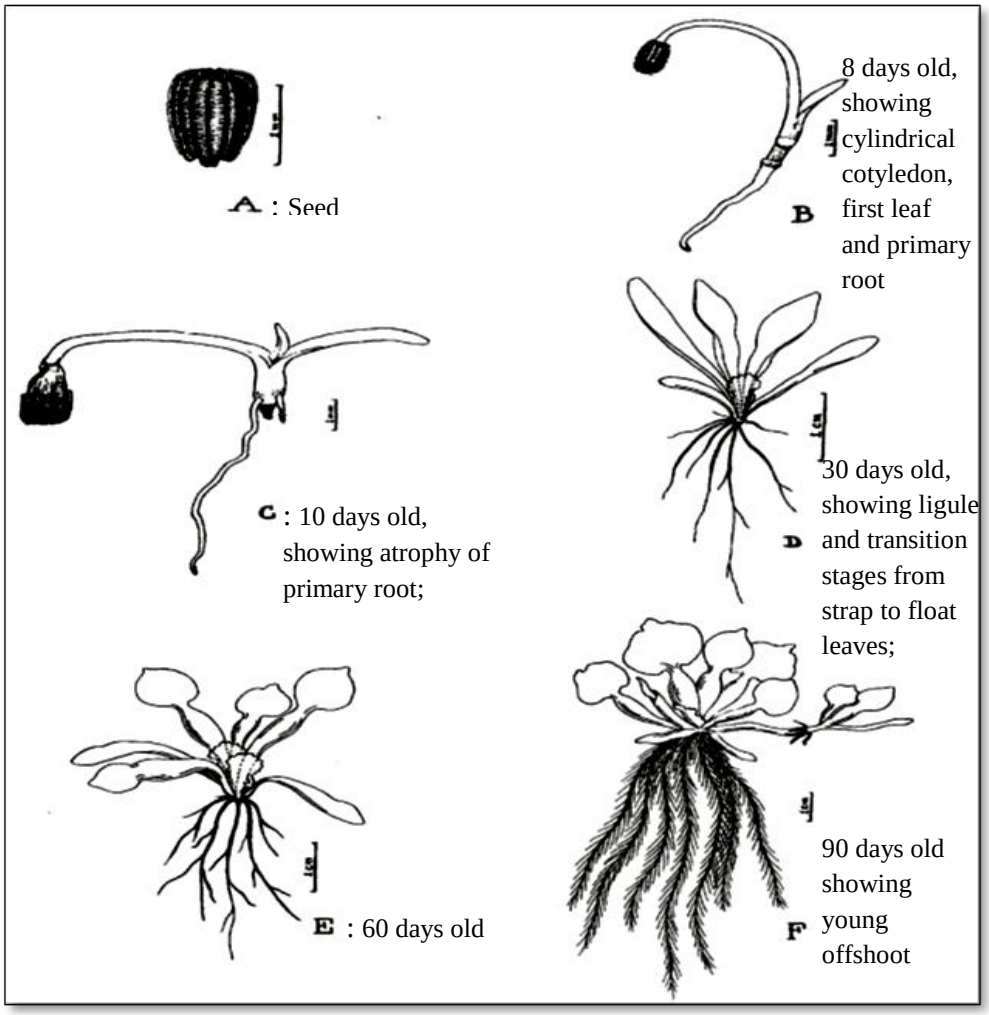


Figure 7: Stages in seed germination in Water hyacinth
Source: Penfound and Earle, 1987

Although water hyacinth is known to reproduce sexually by producing seeds, seedlings and fruits (Barrett, 1980b; Parija, 1934; Haigh, 1936; Penfound & Earle, 1948), seeds do not occur in natural populations in some areas of the world (Müller, 1883; Thomas & Mitchell, 1972; Bock, 1966). This implies that water hyacinth reproduces sexually both in the native and adventive range of its distribution, although, the extent of sexual reproduction and its contribution to the spread of the weed varies greatly in different regions (Gopal, 1987). The quantity of fruits produced as well as the production of mature capsules varies across different regions (De Kimpe, 1957a; Tag el Seed & Obeid, 1975; Penfound & Earle, 1948; Barrett, 1980b). In terms of number of seeds produced per fruit, this is much more variable (De Kimpe, 1957; Tag el Seed & Obeid, 1975 cited in Gopal, 1987; Matthews, 1967;

Penfound & Earle, 1948; Haigh, 1936), with those from the tropics having relatively smaller number of seeds per capsule, but total seed production exceeding that from temperate population because of greater proportion of flower producing capsules (Gopal, 1987).

Flowering as well, does not occur in all plant populations (Freidel *et al*, 1978). Seed production is affected by humidity and temperature. Low relative humidity results in low fruit setting. Maximum fruiting occurs at a relative humidity greater than 90% and temperatures between 22.5^{o}C and 35.0^{o}C (Gopal, 1987). Although the flowers are attractive and well suited for insect pollination, such rarely occurs in nature (Penfound & Earle, 1948). However, insects have been observed to pollinate in some areas of the world. An insect, *Trigona* in Indonesia (Djalilm, 1979) and four groups of bees [*Ancyloscelis sp* and *Megachilidae* and the species of *Trigona*; *Meliponidae* and *Halictidae* were observed to visit flowers in the lower Amazon (Barrette, 1980b).

A number of factors such as climate, absence of pollinating agents, pollen viability, genetic barriers like self-incompatibility and factors affecting seed germination have been considered responsible for limiting the efficiency of sexual reproduction (Gopal, 1987).

On the other hand, vegetative reproduction is a common form of propagation in water hyacinth (Julien *et al,* 1999). The daughter plants produced from the horizontal stolons develop roots and eventually separate from the mother plant following decay or breakage of the connecting stolon. These plants are readily distributed by currents, winds, fishing nets and water craft (Julien *et al;* 1999). Under favourable conditions a single plant can develop into a substantial infestation in a very short time. Doubling days vary from 11.2 days to 15 days (Penfound & Earle, 1948). However, low oxygen tension in infested area slows down vegetative reproduction (Gopal, 1987).

3.6 - Ecology

Water hyacinth grows in a variety of freshwater habitats from shallow temporary ponds, marshes and sluggish flowing waters to large lakes, reservoirs and rivers,

which present a broad spectrum of physio-chemical environments (Gopal, 1987). Optimum growth of water hyacinth occurs in eutrophic, still or slow-moving fresh water with a pH close to 7, a temperature range between 28°C and 30°C, and abundant nitrogen, phosphorus and potassium (Chadwick & Obeid, 1966; Knipling *et al*., 1970; Reddy *et al.*, 1991). Plants will, however, tolerate a wide range of growth conditions and climatic extremes, allowing the weed to infest countries across a wide range of latitudes and climates. Good growth can continue at temperatures ranging from 22°C to 35°C and plants will survive frosting (Wright & Purcell, 1995). Although prolonged cold weather may kill plants, the seeds remain viable (Ueki & Oki, 1979). Plants can infest pristine, relatively low nutrient waterways (Hitchcock, Zimmerman, Kirkpatrick & Earle, 1949) and can survive for several months in low-moisture substrates. They can tolerate acidic waters but cannot survive in salt or brackish water (Penfound & Earle 1948). Water hyacinth flowers year-round in mild climates, producing abundant seeds in developed mats (Penfound & Earle 1948).

Figure 8: Water hyacinth growing with another plant in the Abo creek at Koki village
Photo by Cho Mujingni Jenette, August 2012

Although water hyacinth forms dense free floating mats, covering the surface of the water body where it is present, it also grows in association with a variety of plants depending on the part of the world where it is found. In the Wouri River Basin, it was observed that water hyacinth lives in association with a grass whose name was unknown by the community (Figure 8). It was reported that once water hyacinth

establishes, this grass starts growing with the water hyacinth, intertwine with its mats and form mats which are denser and more difficult to cut.

3.7 - Distribution of water hyacinth in Cameroon

Figure 9: Map of the Republic of Cameroon showing the distribution of water hyacinth.
Source: Modified from http://unimaps.com/cameroon/index.html

Since water hyacinth became visible in Cameroon, it has been reported in rivers Wouri, Nkam and Sanaga in the Littoral region, Nyong in the Centre region, Benoue and Lake Lagdo in the North Region, Lake Maga in the Extreme North region, rivers Sangha , Ngoko, Dja, Boumba in the South and East regions (Forpah, 2009).

3.8 - Distribution of water hyacinth in the Wouri River Basin

Water hyacinth has spread throughout the Wouri River Basin, with complete coverage in some creeks, large patches in some areas and small patches in others. North of the river is mostly affected with complete coverage some creeks (Figure 10). Worth noting is also the port of Douala where large areas of some quays such as that of the fishing port is completely covered with dense mats of water hyacinth (Figure 29).

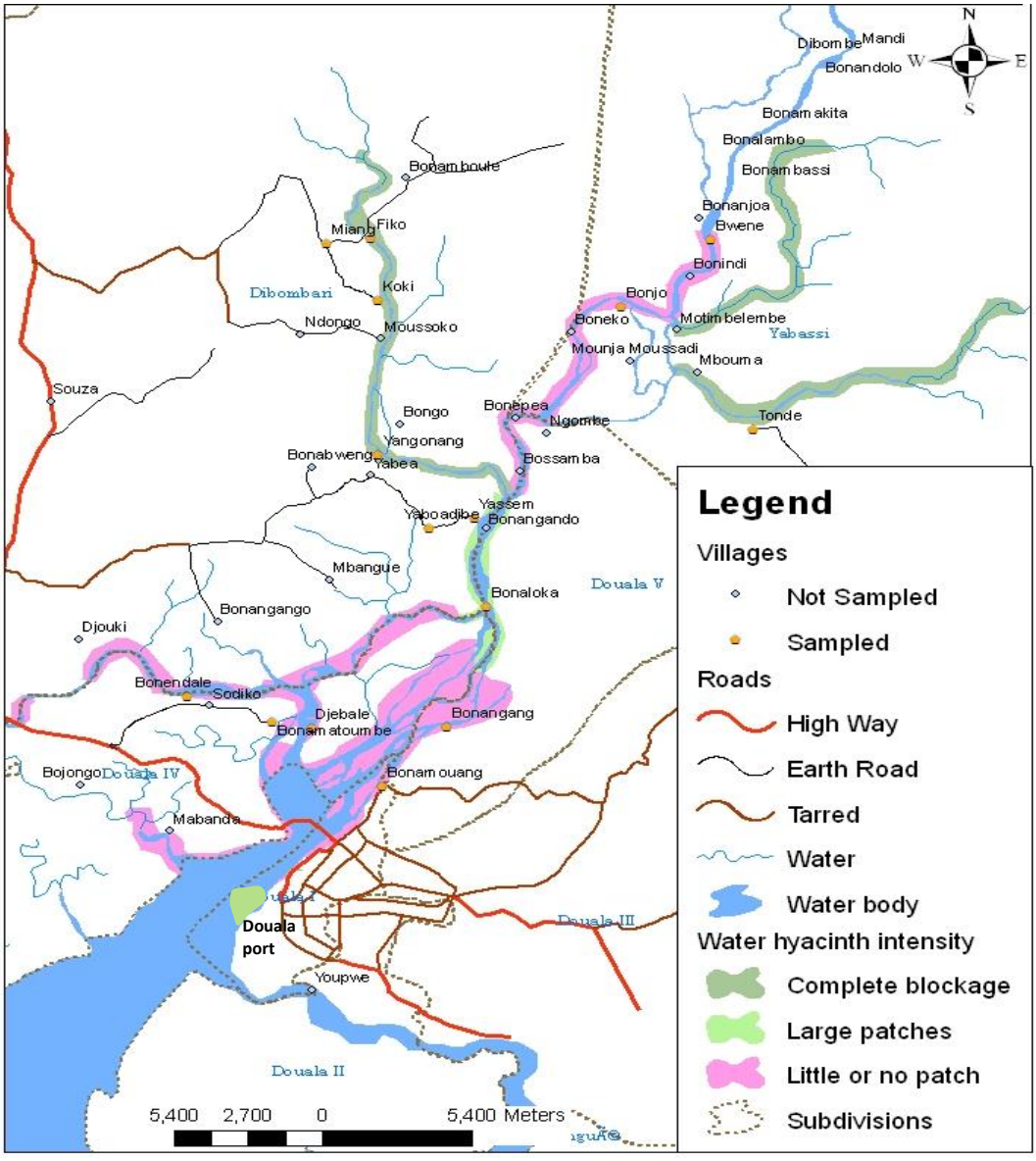


Figure 10: Distribution of Water Hyacinth in the River Wouri Basin.
Produced by Afangang Ernest Ekeocha

Table 2: Total surface area covered by water hyacinth in the Wouri River Basin.

Days	Communities visited	Extent of infestation	Water hyacinth coverage
1	Pillar	High concentration	214,735m^2
	Lobe		
	Bonendale	Patches	
	Tondo		
	Djebale		
	Sodiko		
	Bonamatoumbe		
2	Entrée Mbangue	Patches	53,971m^2
	Bonaloka	> 3 hectares	
	Bonamouang	Patches	
	Kong	Patches	
3	Mbangue	Very high concentration	542,947m^2
	Bonaloka		
	Etia Loka		
	Yassem		
	Bonangando		
	Yabea	~ complete coverage	
4	Bonangando	Moderately high concentration compared to Day 3	138,591m^2
	Katanga		
	Bossamba		
	Etia Bossamba		
	Bonamoumbe		
	Bonandolo		
	Bonepea		
5	Bonamoussadi	None	175,958m^2
	Yassa	High Concentration	
	New Deido	Patches	
	Akwa Nord		
	Bonamouang		
	Mbanya		
	Bonangang		
	Bangue		
	Bonabeyika		
	Casablanca		
	Bonaloka area		
6	Youpwe	None	0
	Manoka		
	Dahomey		
	Sanje		
	Matanda Masidi	no trace due to high salinity in this area	
	Bikoro		
7	Mbanga pongo	None	4m^2
	Bafia		
	Ndogpassi I & II		
	Mabanda	Small concentration	
Total surface area covered by watery hyacinth			**1,122,620.2m^2**
			or 112.26202 ha

Source: Constructed from mapping report of the WTG , 2011

3.9 - Factors influencing the growth of water hyacinth in the Wouri River Basin.

3.9.1 - Climate: The climate of the entire region is equatorial, particularly called "Cameroonian", characterized by a long rainy season that lasts for nine months with rainfall of average 4m per year in Douala (Din, 2007). Average annual temperatures are high (26.7°C) and relatively constant. The wind speed is low (< 3 m/s) outside the periods of installation and removal of the monsoon (Din, 2007). Among major climatic factors, rainfall, temperatures and winds have a significant influence on the composition and quality of the vegetation of the forest areas (Din, 2007).

3.9.2 - Salinity: The hydrology of the Wouri River is influenced among other factors by the general scheme of the Bight of Biafra, climate, topography and geomorphology (Din, 2007). The mass of surface water remains warm between 25 – 28°C throughout the year with relatively low salinity less than 35g/l (Din, 2007). In the estuary, the salinity is always less than 20g/l and the dilution is very fast. Less than 30 km from the Atlantic Ocean, salinity is zero or almost zero for much of the year due to inputs of fresh water from the rivers that feed the estuary (Din, 2007). The annual variation of salinity in the Wouri is between 0 and 2g/l. During the long rainy season, the salinity of water that irrigates the aquatic ecosystems and hydromorphic of the Wouri is always less than 10g/l and in the dry season, measurements show between 4 and 20g/l (Din, 2007).

3.9.3 - Tides: Tides influence the structure, composition and distribution of mangrove vegetation. Similarly, they affect soil salinity and the rate of evaporation. In return, they are influenced by wind, precipitation regimes and rivers (Din, 2007). The tidal regime is semi-diurnal in Cameroon with maximum amplitude of about 3m. Circulation patterns in estuaries depend on the interaction between tides and river flows. When the tidal range is small, the less dense freshwater spreads over salt water causing a vertical stratification of the water column (Din, 2007). When the tidal range is large, the turbulence is much greater and the water column becomes homogeneous. Tides therefore play an important role in plant nutrition and the spread of the species. Tides are able to install and expand water hyacinth as they can degrade, and consequently leading to the spread of the plant (Din, 2007).

3.9.4 - Nutrients: The rapid proliferation of water hyacinth and other aquatic vegetation in the Wouri River is also influenced by many organic inputs from urban and industrial activities that alter natural physiochemical parameters of water and cause significant changes in the ecosystem (Din, 2007). The cluster of industries in this area, the rapid increase in population and corresponding increase in activities enrich the water bodies with nutrients leading to pollution (Din, 2007). Large urban sewers and other effluent discharges are well known sources of point water pollution, while extensive uses of improper agricultural methods, and land uses that often result in soil erosion, are a major source of non-point water pollution. Although household waste plays a greater role in pollution, reports indicate that industrial waste alone is estimated at about 2,187 metric tons per year in biochemical oxygen demand and about 48,000 metric tons per year in suspended solids in the Cameroon's coastal city of Douala alone (UNEP,1982 cited in Dieudonne, 2006). All these favour the bloom of water hyacinths in the Wouri River Basin.

3.9.5 - Ballast water: The city of Douala is host to the country's largest port which welcomes ships every day from countries all over the world. Just like other invasive species, water hyacinth is carried in ballast water which is often exchanged at the ports at berth. Branches of water hyacinth from other countries are therefore deposited in the river, which anchor and start proliferating where conditions are favourable.

3.10 - Impacts on riparian communities

Water hyacinth infestation has resulted in serious social, economic and environmental problems for millions of people in riparian communities all over the world.

3.10.1 - Social impacts

Hunger and Protein deficiency: Reports from around the world indicate some villages where people have died from heavy water hyacinth infestations; notably through starvation because they could not reach food sources and protein deficiency resulting from unavailability of fish (Navarro & Phiri, 2000).

Health hazards: Bites of venomous snakes and attacks by crocodiles taking shelter in water-hyacinth mats, diseases such as malaria carried by mosquitoes or bilharzia carried by snails that breed in water hyacinth environments as well as cholera from the drinking of water polluted by water hyacinth, are some of the health problems associated with water hyacinth infestation. Also people often collapse due to fatigue from pushing canoes through clogged waterways (Navarro & Phiri, 2000). Although it is difficult to establish the statistical link between water hyacinth infestation and some diseases, it can be shown that the brughian type of filariasis (which is responsible for a minor share of lymphatic filariasis in South Asia) is entirely linked to the presence of aquatic weeds (Haider, 1989).

Hindrance to recreational activities: As part of their social activities, riparian communities derive recreational benefits from the river where activities like boat racing, swimming and site seeing are organized. This can no longer be possible in water hyacinth infested areas.

3.10.2 - Economic impacts

Hindrance to water transport: Access to harbours, channels and docking areas can be seriously hindered by mats of water hyacinth (Calvert, 2002). Canals, river tributaries, waterways and fresh water rivers can become impassable as they become clogged with densely intertwined carpets of the weed (Ndimele *et al*, 2011). In the Wouri River Basin, the entire Abo and *Moundja Moussadi* creeks have been rendered impassable by this aquatic weed.

Problems related to fishing: Water hyacinth causes severe problems to fishermen in the riparian communities. When weed infestation is present, access to fishing sites become difficult for riparian communities which rely solely on fishing as their main economic activity. This leads to increase in their expenditure on fuel for engine boats and further increase in the cost of the meagre quantities of fish they catch, for the society as a whole. There is often loss of fishing gears when nets or lines become tangled in the root systems of the weed. The people of Bonaloka in the Wouri River Basin reported losses of about 3 fishing gears annually due to water hyacinth, leading

to expenditure of about 90.000FCFA (US$ 180) annually for the purchase of new fishing gears of 45m long. All these lead to reduction in fish catch and subsequent loss of livelihood. Majority of the villages in the Wouri River Basin have abandoned fishing which is their main occupation, for other activities like farming.

Loss of income from tourism: Another sector that contributes to economic growth is tourism. Estuaries are very good touristic sites where thousands of tourists from all over the world derive pleasure. Water hyacinth infestation affects tourism, as their access to the beautiful view of the estuaries becomes limited. In addition, they have difficulties in accessing the inland waterways by boats due to blockage of by water hyacinth. In this regards, the riparian communities are affected because their commercial activities are usually boosted by tourists.

Clogging of irrigation, hydropower and water supply systems: Many large hydropower schemes are suffering from the effects of water hyacinth (Center *et al*, 2002 cited in Ndimele *et al*, 2011). The Owen falls hydropower scheme at Jinja on Lake Victoria is a victim of water hyacinth's rapid proliferation and huge sums of money has been spent on physical removal to prevent it from entering the turbine and causing power interruption (Mailu, 2001). The Kariba dam which straddles the Zambia-Zimbabwe border on the Zambezi River is heavily infested by the weed (Mailu, 2001).

3.10.3 - Environmental Impacts

Potential for Floods: Water hyacinth mats when allowed to grow uncontrolled, can block canals and rivers leading to flooding. The communities of Bwene and Bonjo in the Wouri River Basin suffer from floods regularly during the rainy season due to blockage of waterways around these villages by water hyacinth.

Degradation of water quality: The most apparent environmental impact of water hyacinth infestations that affect the riparian community directly is the degradation of water quality by its foul smell and debris. The death and decay of water hyacinth vegetation in large masses may create anaerobic conditions and production of badly smelling or even lethal gases (Mailu, 2001)

Siltation: The blockage of waterways by water hyacinth increases siltation and hinders activities like swimming, fishing and sand extraction, as, mud is mixed with sand. Water hyacinth reduces the flow of the river leading to accumulation of debris, mud and sand which reduces the depth of the river.

Reduction in biodiversity: Other environmental impacts of water hyacinth include its interference with diversity and distribution of life in aquatic environments (Mailu, 2001). Where the water hyacinth is prolific, other aquatic plants have difficulty in surviving, leading to an imbalance in the aquatic micro-ecosystem and this often implies that a range of fauna that relies on a diversity of plant life for its existence will become affected. Diversity in fish stocks is often affected with some benefiting and others suffering from the proliferation of water hyacinth (Calvert, 2002). In some parts of the world other types of plant grow where water hyacinth infestation occurs. Mailu, (2001) reported that in Lake Victoria, pure mats of water hyacinth were invaded initially by aquatic ferns/sedges (*Cyperus papyrus* and *Ipomea aquatica*) often to be followed by hippograss (*Vossia cuspidator*) which invariably eventually dominated the infested area.

Increased Evapotranspiration: Studies have shown that a dense cover of water hyacinth enhances evapotranspiration (Mailu, 2001). The rate of water loss due to evapotranspiration can be as much as 1.8 times that of evaporation from the same surface but free of plants (Haider, 1989). This has great implication where water is already scarce.

Chapter four

Quantification of the impacts of water hyacinth on riparian communities in the wouri river basin

4.1 - Introduction

River Wouri, one of the most important rivers in Cameroon provides livelihood for close to 900,000 people living in the basin. Since water hyacinth arrived in this basin around the late 1990s, it has caused severe socioeconomic and environmental problems to the riparian communities. Its growth is very rapid and has already covered more than 14,000 ha in the Wouri River Basin (WTG, 2011).

The study area covered the four departments of the Littoral region. The Wouri River receives rivers Moungo and Dibamba, and has several connections with the Sanaga, before emptying into the Atlantic Ocean. The Wouri River is in a state of permanent vulnerability because of infestation of its tributaries by water hyacinth. The watershed extends the Wouri River on the southern part of the Moungo division, the south-western area of the Nkam division and invaded a significant portion of the north-southern division of Wouri. Currently the units affected most by water hyacinth are found in the districts of Dibombari, Fiko, Douala I, IV, V and Yabassi.

This chapter presents data collected in an attempt to assess and quantify the socioeconomic and environmental impacts of water hyacinth on the riparian communities in the Wouri River Basin. The report draws on field observations, interviews of affected communities and focused group discussions with targeted groups of users of the river.

The research period was six days and the villages visited were as follows: Fiko, Koki, Miang, Yabea, Yassem, Yangonang, Bonjo, Bonamembe, Sodiko, Djebale, Bonaloka, Tonde, Mambanda, Bonamatoumbe, Bonangang, Bonamouang, Bangue, and Bonamoussadi. There are many villages in the Wouri River Basin but the above villages were sampled based on a mapping report on the distribution of water hyacinth carried out in 2011 by WTG in Cameroon, where the above areas reported the highest concentration of water hyacinth.

4.2 - Resources used

4.2.1 **Human resources**

Mr. Afangang Ernest, a GIS/GPS Consultant, provided his expertise on the use of GIS and GPS during the process, and Mr. Elvis Ndipmun, MSc. in Port and Shipping Management from the Regional Maritime University (RMU) accompanied me to the villages, Mr. Manga Dudu was the engine boat pilot and bike and car drivers were also used.

4.2.2 **Material resources**

a) Topographic maps were used to situate the sampled villages or communities within the study area, identifying accessible areas, potential hot spots for field visitation and to know the nature of the terrain.
b) Global Positioning System (GPS) was used to collect coordinates of the sites identified or visited during the research. Features such as roads, footpath tracks were track-logged while the GPS point coordinates were collected for discrete features such as sampled sites, villages visited and other features relevant to the study.
c) Geographic Information System (GIS) was used to produce maps from some data collected as lines or points that were plotted, coupled with those extracted from the topographic map.
d) A pen and note book was used to collect descriptive data about the coordinates of features recorded in the GPS and also to note the impacts of water hyacinth as stated by the inhabitants of these communities.
e) Cameras were used to take snap shots of strategic places occupied by water hyacinth.
f) A car, a paddling boat, an engine boat and bikes were used as means of transport to the various sampled villages as the need be.
g) Interviewer's Guide Questionnaire (IGQ) was used to guide the researcher on the field during interviews and focus group discussions.
h) Measuring tape was used to make measurements where necessary.

4.3 – Methodology

Figure 11: Schematic representation of the chosen methodology

1) Focused Group Discussion (FGD) was used as the method to collect information from targeted groups of inhabitants and users of the Wouri River. The targeted groups included fishermen, transporters, sand extractors, hunters and palm wine tappers.
2) Interviews were carried out on individuals who were identified as users of the river, administrative authorities from selected ministries as well as NGOs and other institutions that have shown concern on the control of water hyacinth in Cameroon.
3) Observations were made at various points during the study.

16 villages and 4 ports in the Wouri River were sampled and to ease reporting, the sampled villages and ports were classified into five areas. These include the Abo, Ewodi, Bakoko, Bonaberi, Bonamoussadi and port areas (Table 3). A total of 50 people were interviewed which includedn10 focused group discussions with an average of 4 people per group and 9 individuals. Administrative officials from the MINT and the MINEPIA, and a staff from WTG were equally interviewed (List of interviewees in Annex 1)

Table 3: Sampled riparian communities in the Wouri River Basin

Villages	Fiko	Buene	Yassem	Bonendale	Bonamouang	Fishing port
	Koki	Bonjo	Yangonang	Bonamatoumbe	Bonangang	Container terminal
	Miang	Bonaloka	Yaboadibe	Djebale	-	CNIC
	Bongo	Tonde	-	-	-	UIC
Areas	Abo	Ewodi	Bakoko	Bonaberi	Bonamoussadi	Port

Before water hyacinth became a menace in these areas, the villages of the Abo and Bakoko areas derived their livelihood from the Abo creek. The creek is 20.8km long and 40m wide. The bridge across the creek (the Fiko Bridge) is 257m long. The Abo creek was a very important source of livelihood for the inhabitants of these villages, providing fish for both commercial use and for subsistence as a source of protein. Fishing and farming were the major economic activities being carried out by this community. The following types of fish were available in this creek; *inter alia*, Mbem (dog fish), *Ngunu* (Mud fish), *Malepe* (Tilapia), *Biondo* (Calpe), *Mallay, Mbamteh, Ngonteh.* The creek also served as a major route for transportation of goods such as fish as well as people to the city of Douala and other villages in the north and south of the river. Villagers who have farm lands, hunting and palm wine tapping sites across the creek also used the creek to get to these sites. Sand extractors resident in the villages extracted sand from the river, which was not sold, but used for construction of their houses. This made them save a lot of money from buying sand from the city and transporting it to the villages through the roads which were not readily accessible by cars. Furthermore, there was no source of drinking water; hence, they relied on the river for drinking as well as laundry and bathing.

For entertainment, swimming and canoe race competitions were organized regularly by the chief or the youths and prizes were won. These were their main recreational activities that kept their lives going and made life in the village interesting. Also, tourists and researchers used to visit these villages, accessing them through the Abo creek. There existed a market at the banks of the river in this area where traders left the city of Douala and other towns and came there to buy fish to go and sell.

This was the good life that existed from the time these people settled in the area until between 1997 and 2002 when all the fortunes of the river, the booming of socioeconomic activities and the good life lived by the inhabitants turned to a nightmare with the arrival of the “beautiful devil”, water hyacinth. Presently the Abo creek is completely blocked with water hyacinth (Figure 12). This led to a complete halt in all the socioeconomic activities of the people of this area.

Figure 12: View of the Abo creek from both sides of the bridge at Fiko, completely covered by water hyacinth
Photos by: Cho Mujingni Jenette, August 2012

The villages of the Ewodi area are not different from the Abo. Their main economic activities are also fishing, farming and sand extraction. They obtained their livelihood from the *Moundja Moussadi* creek and two other creeks in this area which are completely blocked by water hyacinth. The *Moundja Moussadi* creek is about 16.4km long and 35m wide. They obtained same benefits from these creeks like the people from the Abo area. The people of Bwene and Bonjo reported death cases due to water hyacinths. The victims either drowned when swimming and found themselves under the water hyacinth mat which prevented them from getting to the surface of the water or when they fell overboard from a boat. They reported an average of 3 deaths every year through these circumstances. Notably is the case of Mr. Ekule Emmanuel's 14 years old daughter who drowned under water hyacinth mat in Bwene village in 2007.

Figure 13: View of the *Moundja Moussadi* creek in Tonde, completely covered by water hyacinth. The villagers regularly cut the water hyacinth to pave way for boats to pass (left) and open their landing site (right). Photos by: Cho Mujingni Jenette, August 2012

The communities of Bonaberi and Bonamoussadi mainly carry out sand extraction as their main economic activity. These areas are urban areas and their population include people from other regions who come to Douala for employment and business opportunities. Fishing therefore is not their primary economic activity. However, they carry out fishing on a small scale for home consumption; hence, they are faced with water hyacinth problems too. Their main problem with water hyacinth is the interruption of their activities by "islands" of floating water hyacinths. The stolon of water hyacinth breaks easily when it encounters strong waves or floods. When this happens, huge "islands" of water hyacinth dislocate from the highly infested areas, are carried by waves and drift down the river. During sand extraction, the diver sometimes collides with these islands of water hyacinth when coming up to the surface of the water with his bucket of sand.

Figure 14 : Transportation of sand to sand depot after extraction from the river Wouri basin (left) and loading activities in a sand depot in Bonangang (right)
Photos by: Cho Mujingni Jenette, August 2012

This often leads to fatigue because as the diver may hit his head hard on the heavy bunch of water hyacinth several times if he does not notice it. If he notices it, he is forced to dive back under the water with his sand to allow the drifting island of water hyacinth to pass before he comes up or he comes up in another area which is free.

Floating water hyacinth also destroys their boats. During sand extraction, the boats are anchored in the middle of the river. The floating water hyacinth which is very heavy, often hooks on their anchor rope and cuts it, releasing the boats which are

swept away by waves to distances of about 5 to 8km. When this happens, the owners pay between 30,000 FCFA (60 USD) to 50,000 FCFA (100 USD) for the boat to be brought back. This happens averagely 2 times a week, mostly during the rainy season which is the period when water hyacinth bunches break off easily as a result of increased wave action. The same scene occurs at the sand depots where the boats are berthed.

Furthermore, since their sand depots are as far as 10 to 15 km away from their sand extraction sites, the extracted sand needs to be transported to the depots. Water hyacinth is also a problem during transportation of the sand. When the diver encounters a very huge island of floating water hyacinth, he needs to alter course to avoid the water hyacinth. If this is not done, the boat collides with the water hyacinth and the water hyacinth propels the boat right to a position where neither the water hyacinth bunch nor the boat can go further, like in mangroves. When this happens, the transporter needs assistance to remove the boat from that position and this service is usually paid for an average o10,000 FCFA (20 USD). During other encounters, the boat may capsize, pouring all the extracted sand back into the river. Problems of this type are rare but they do occur once in a while.

4.3 - Presentation and analysis of data

4.4 .1 – Impact on major economic activities

Data on the major economic activities carried out by the riparian communities before and after water hyacinth became a menace was collected and results presented. These activities include those that are carried out for commercial purposes. Social and environmental impacts were also quantified. Quantification was in terms of monetary value, quantities, percentages, increase or decrease and importance.

Fishing: The main areas where large scale fishing is carried out are the Abo, Bakoko, Ewodi and Bonaberi areas. There, the following problems regarding the interference of water hyacinth on fishing activities were reported:

- reduced quantities of fish caught;
- destruction of fishing gears by water hyacinth mats;

- disappearance of some important species of fish;
- no or limited access to fishing sites and
- reduction in size of the fishing area in some areas and complete

Statistics show more than 90% reduction in the number of fishermen and similar percentage in the average quantity of fish caught by the sampled communities after water hyacinth became a menace. There is a relatively higher quantity of fish caught in Tonde and Bonjo after water hyacinth became a menace. This is because the people of Tonde organise regular clean up campaigns to open up the *Moundja Moussadi* creek; hence, fishing is still carried out to a certain extent in these areas. The Bonjo people, on the other hand, have only patches of water hyacinth along the shores of the river, so their fishing activities are still going on and are relatively not so much affected. Also, a few fishermen are left in Djebale because in this area, the river is salty so water hyacinths do not thrive there as much as the other areas; hence, the impact is not felt so much. Miang had the highest number of fishermen before water hyacinth became a menace because it is the biggest village in that area and has the highest population. Besides, their main economic activity was fishing.

Table 4: Statistics on fishing activities carried out by the sampled population before and after water hyacinth became a menace

Area	**Village**	**N° of fishermen**		**Average daily Catch per fisherman per day (Kg)**	
		Before	**After**	**Before**	**After**
Abo	Fiko	12	0	60	0
	Koki	400	6	90	1.5
	Miang	2250	0	60	0
	Bongo	130	3	60	2
Bakoko	Yassem	100	20	60	2
	Yangonang	200	0	90	0
	Yaboadibe	200	25	60	3
Ewodi	Bwene	250	0	60	0
	Bonjo	20	12	30	20
	Bonaloka	170	15	30	1
	Tonde	150	20	90	23
Bonaberi	Bonamatoumbe	100	30	30	1
	Djebale	400	175	200	3
Total		**4382**	**306**	**920**	**56.5**
		% drop = 93%		**% drop = 93.9%**	

The high drop in the quantity of fish in the river was also associated to poor fishing practice carried out by some fishermen. The use of chemicals such as gamaline to kill fish, has been noted in this area (MINEPIA, 2012).

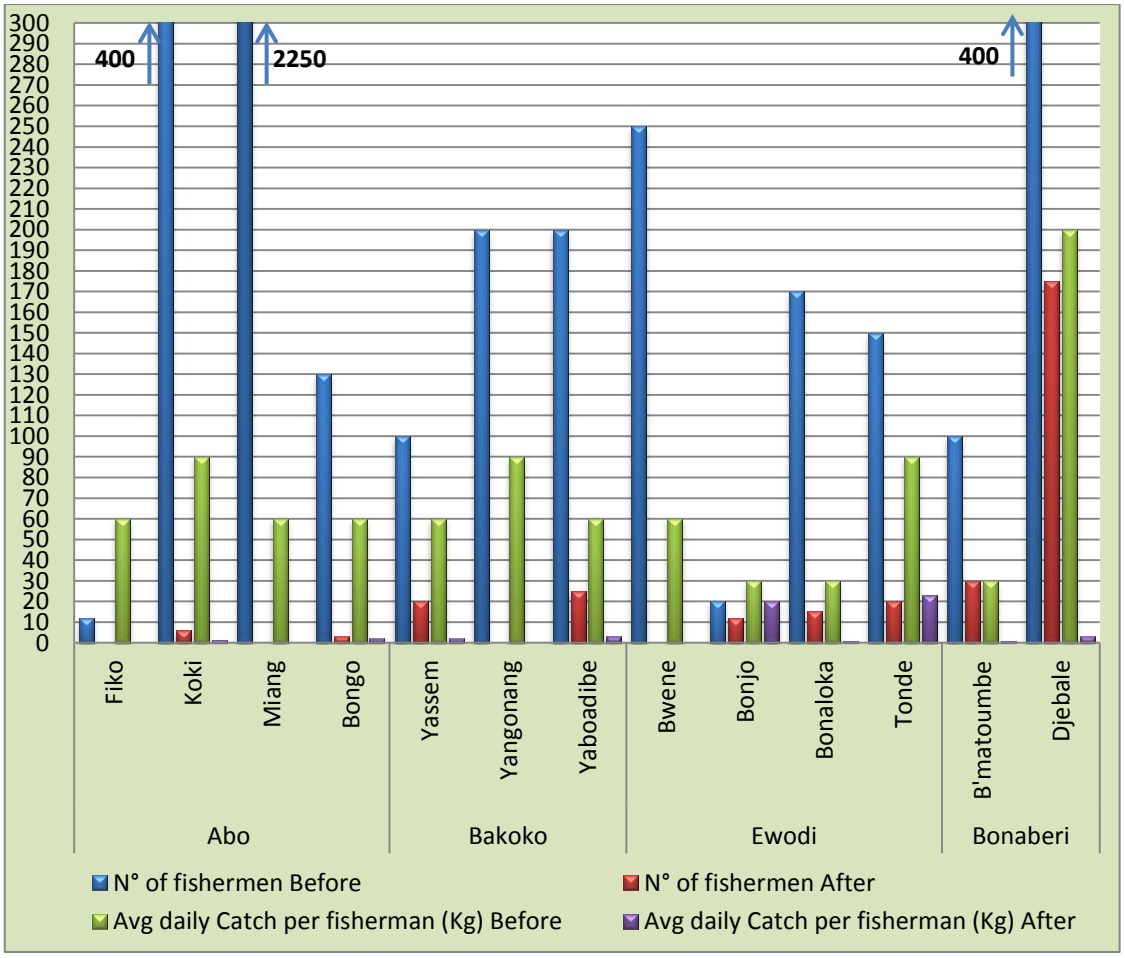


Figure 15: Fishing activities in the sampled villages before and after water hyacinth became a menace

In addition to the drop in number of fishermen and quantity of fish caught, there is a corresponding decrease of more than 90% in the income obtained from the sales of fish across all the villages (Table 5). Some villages like Fiko, Koki, Bonaloka and Bonamatoumbe have suffered most. They do not fish for commercial purposes anymore. However, in Bonaloka it was reported that when they need to sell, they collect small quantities every day for about two weeks and preserve either by smoking or in fishing baskets positioned in the river near the shore, to obtain a significant quantity that can be taken to the market at Tonde or Douala.

Table 5: Statistics on the average daily income from sales of fish by the sampled population before and after water hyacinth became a menace

Area	Village	Average daily income (FCFA)	
		Before	**After**
Abo	Fiko	60000	0
	Koki	90000	1500
	Miang	60000	0
	Bongo	60000	2000
Bakoko	Yassem	60000	2000
	Yangonang	90000	0
	Yaboadibe	60000	3000
Ewodi	Bwene	60000	0
	Bonjo	30000	20000
	Bonaloka	30000	1000
	Tonde	90000	23000
Bonaberi	Bonamatoumbe	30000	1000
	Djebale	200000	3000
Total		**920000**	**56500**
Note: 500 FCFA = 1USD		**1768 USD**	**124 USD**
1 kg = averagely 1000FCFA		**% drop = 93.9%**	

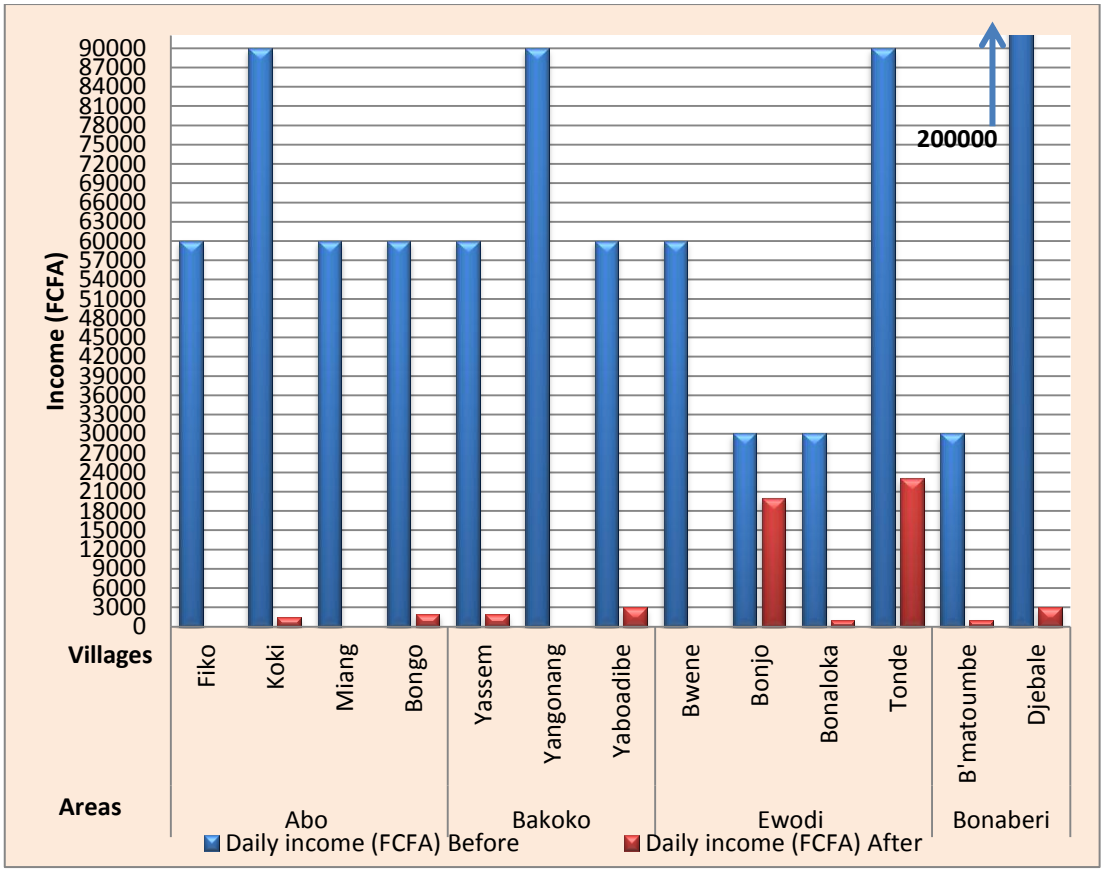


Figure 16: Average daily income from sales of fish by sampled population before and after water hyacinth became a menace

Sand extraction: Statistics on the number of sand extractors, the quantity of sand extracted and income from sales of sand before and after water hyacinth became a menace were collected and represented in Tables 6 and 7. Among the sampled riparian communities, only those indicated in Table 6 carry out sand extraction.

Table 6: Statistics for sand extraction activities before and after water hyacinth became a menace

Area	**Village**	**N° of sand extractors**		**Quantity (m^3/week/extractor)**	
		Before	After	Before	After
Abo	Fiko	2	0	3	0
	Koki	1	0	24	0
	Miang	25	0	12	0
Bonamoussadi	Bonamouang	125	100	72	36
	Bonangang	100	110	72	36
Bonaberi	Bonendale	20	17	24	18
Ewodi	Tonde	25	10	9	6
Total		**298**	**237**	**216**	**96**
Note: 1 sand boat = $6m^3$		**% drop = 20.2%**		**% drop = 55.6%**	

The results show a decrease in the number of sand extractors of over 20% and a corresponding close to 60% decrease in the quantity of sand extracted every week. After water hyacinth became a menace, no village in the Abo area could extract sand anymore due to complete blockage of the Abo creek by water hyacinth. In Tonde, on the other hand, there is limited possibility because although the *Mundja Moussadi* creek was completely blocked, the people regularly cut the water hyacinth mats and open the river before they can carry out this activity or pave their way to other sand extraction sites. The divers from Bonamouang and Bonangang which harbour the biggest sand depots in the Bonamoussadi area reduced their activities from twice a day to once a day especially during the rainy season when waves always carry tufts of water hyacinth down river, which disturbs sand extraction activities. However, the reduction in the quantity of sand extracted by Bonamouang and Bonangang divers is not solely due to water hyacinth. It is partly due to the proliferation of other sand depots in the Moungo division that has made demand in the Bonamoussadi area to drop, despite the general increase in demand for sand as a result of an increase in

developmental projects in and around Littoral region. Also, sand extractors increased in Bonangang even after water hyacinth became a menace. This is because this sand depot is very organized and the divers here take care of each other in times of need through contributions and savings. This attracts more divers into the business despite its risks and drop in demand in the area.

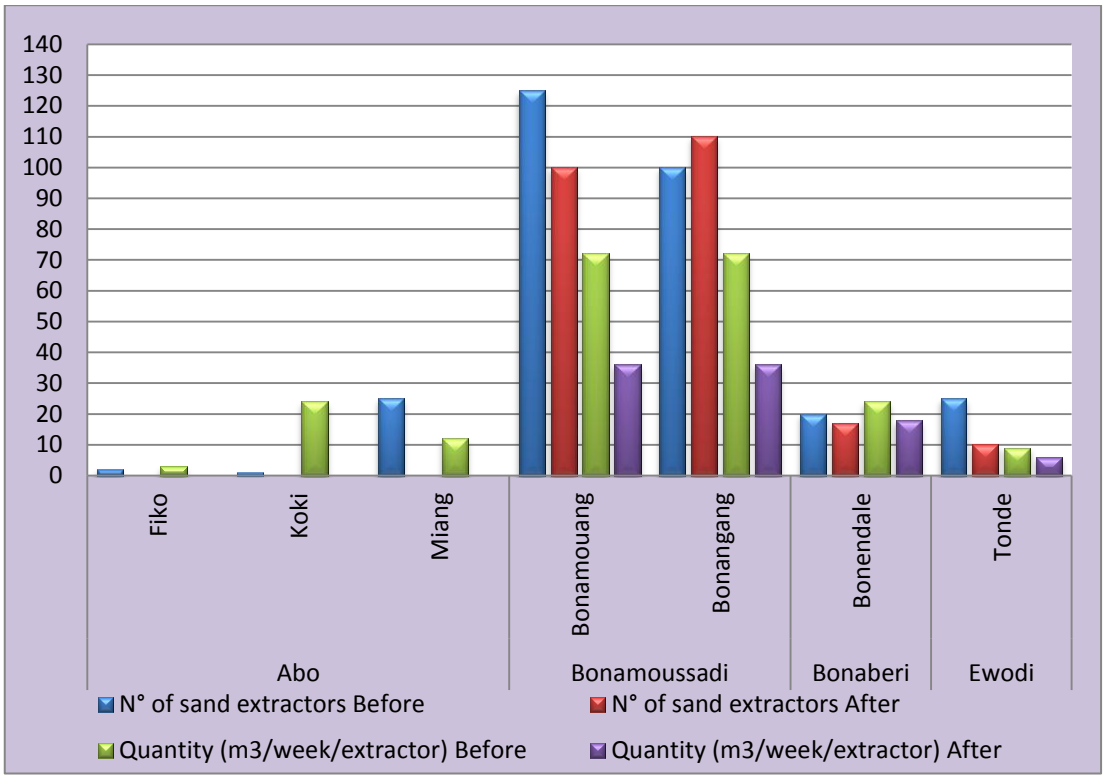


Figure 17: Sand extraction activities in the Wouri River before water hyacinth became a menace.

For sales of sand there is a 40% increase in income from sales of sand by these communities (Table 7). This is because even though the quantity of sand extracted decreased after water hyacinth became a menace, there was a general 33.3% increase in the price of a $6m^3$ boat of sand. This increase is due to high demand of sand in the region. This further led to about 40% increase in income from the sales of sand. It implies that sand extraction is very lucrative in the Littoral regional; hence, if there were no disturbances in this activities, there would have been more extractors, more quantity of sand extracted and hence more income.

Table 7: Statistics for average weekly income from sales of sand before and after water hyacinth became a menace

Area	Village	Average weekly income per extractor	
		Before	**After**
Abo	Fiko	5,000	0
	Koki	40,000	0
	Miang	20,000	0
Bonamoussadi	Bonamouang	12,000	90,000
	Bonangang	12,000	90,000
Bonaberi	Bonendale	40,000	45,000
Ewodi	Tonde	15,000	15,000
Total		**144,000**	**240,000**
		% increase = 40%	

Note:	
Before	After
$6m^3$ = 10,000 FCFA	$6m^3$ = 15,000 FCFA
% increase = 33.3%	

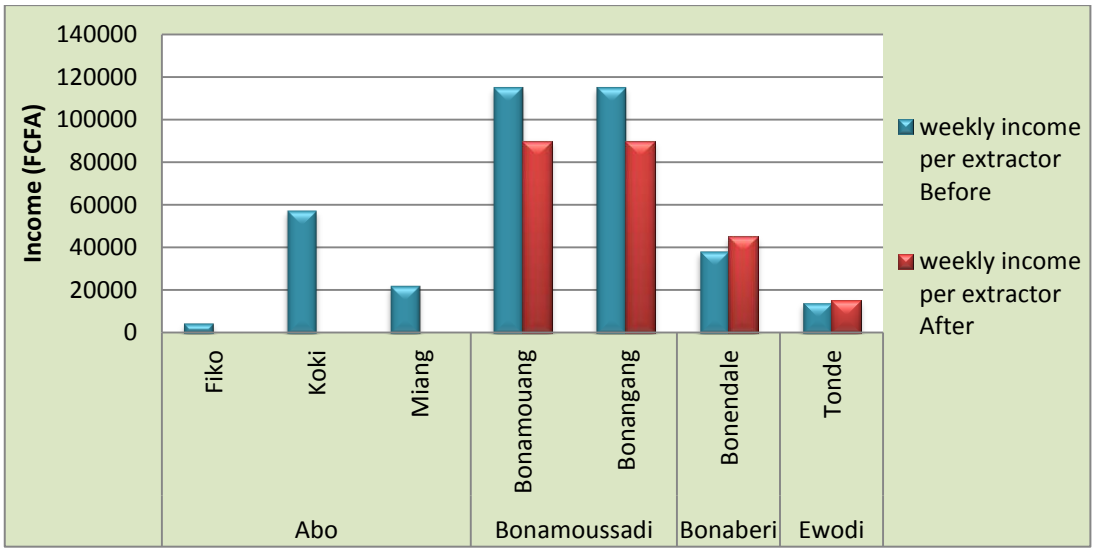


Figure 18: Average weekly income from sales of sand before and after water hyacinth became a menace.

Transportation: All the riparian communities use the river for transportation from one village to the other and also to other cities and towns like Douala and Yabassi. However, the statistics here presented, compares the time spent for transportation by land and river during and after water hyacinth became a menace as well as the cost of transportation by these means during the same period to the city of Douala (Table 8 and 9 respectively).

Table 8: Statistics on transport activities in river Wouri before and after water hyacinth became a menace (time spent to Douala by land and the river)

Area	Village	Avg. time spent for transportation (Minutes)			
		Land		River	
		Before	After	Before	After
Abo	Fiko	130	100	260	0
	Koki	145	110	240	0
	Miang	120	90	260	0
	Bongo	135	120	240	0
Bakoko	Yassem	120	60	180	180
	Yangonang	105	45	240	0
	Yaboadibe	120	60	180	0
Bonamoussadi	Bonamouang	15	15	0	0
	Bonangang	20	20	0	0
Bonaberi	Bonendale	45	45	0	0
	Bonamatoumbe	60	60	60	60
	Djebale	0	0	60	60
Ewodi	Bwene	0	0	240	240
	Bonjo	0	0	210	210
	Bonaloka	0	0	135	135
	Tonde	45	45	240	0

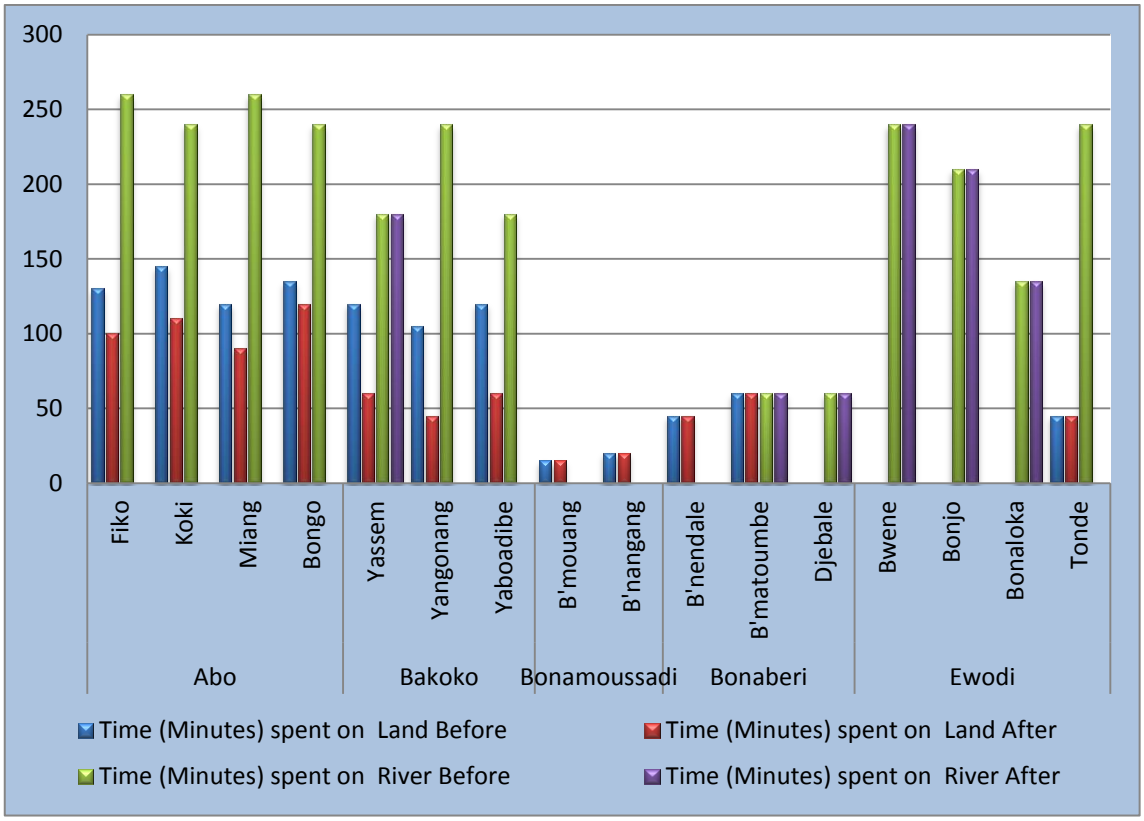


Figure 19: Time spent for transportation to Douala by riparian communities before and after water hyacinth became a menace.

The result indicates that more time was spent to go to Douala by the river than by land especially for the upriver communities like Abo and Bakoko (Table 8) before water hyacinth became a menace. However, they did most of their transportation by the river. This is because each household in these communities owned at least a paddling boat which they used for transportation, whereas, by land the roads were not tarred; hence, not readily accessible especially during the rainy season. In addition, only bikes went there a few times in a day, such that they had to wait for hours to get a bike to go to the city. Also, they rarely paid their way via the river to Douala because they owned paddling boats, but when need arose; it was cheaper, shorter and less strenuous using engine boats than going by land. Cars or bikes don´t go to Koki village except they are hired because of a steep hill that descends to the village. The people of Koki go to Miang to get a bike to the city.

Table 9: Statistics on the cost of transport in Wouri River before and after water hyacinth became a menace compared with that on land**.**

Area	**Village**	**Cost of transportation (FCFA)**			
		Land		**River**	
		Before	**After**	**Before**	**After**
Abo	Fiko	1500	2000	700	0
	Koki	1500	2000	700	0
	Miang	1500	2000	700	0
	Bongo	1500	2000	500	0
Bakoko	Yassem	1500	2500	500	1000
	Yangonang	1500	2000	500	1000
	Yaboadibe	1500	2500	500	1000
Bonamoussadi	Bonamouang	150	200	0	0
	Bonangang	150	200	0	0
Bonaberi	Bonendale	300	400	0	0
	Bonamatoumbe	500	700	250	250
	Djebale	0	0	250	250
Ewodi	Bwene	0	0	1000	1500
	Bonjo	0	0	700	1000
	Bonaloka	0	0	700	1000
	Tonde	700	1000	700	0
Total		**12300**	**20000**	**7700**	**7000**

Around 2002, the roads halfway to these communities were tarred (see Figure 4, page 16) but by then water hyacinth had blocked the Abo and the *Moundja Moussadi*

creeks. The Abo community could no longer travel to Douala by the river till today. Also, although the people of Tonde regularly cut the water hyacinth to pave their way, they prefer going to the city by road because it is shorter. Yangonang and Yaboadibe communities don't go to Douala by the river anymore but when need arises, they go to Yassem and wait for a passing engine boat.

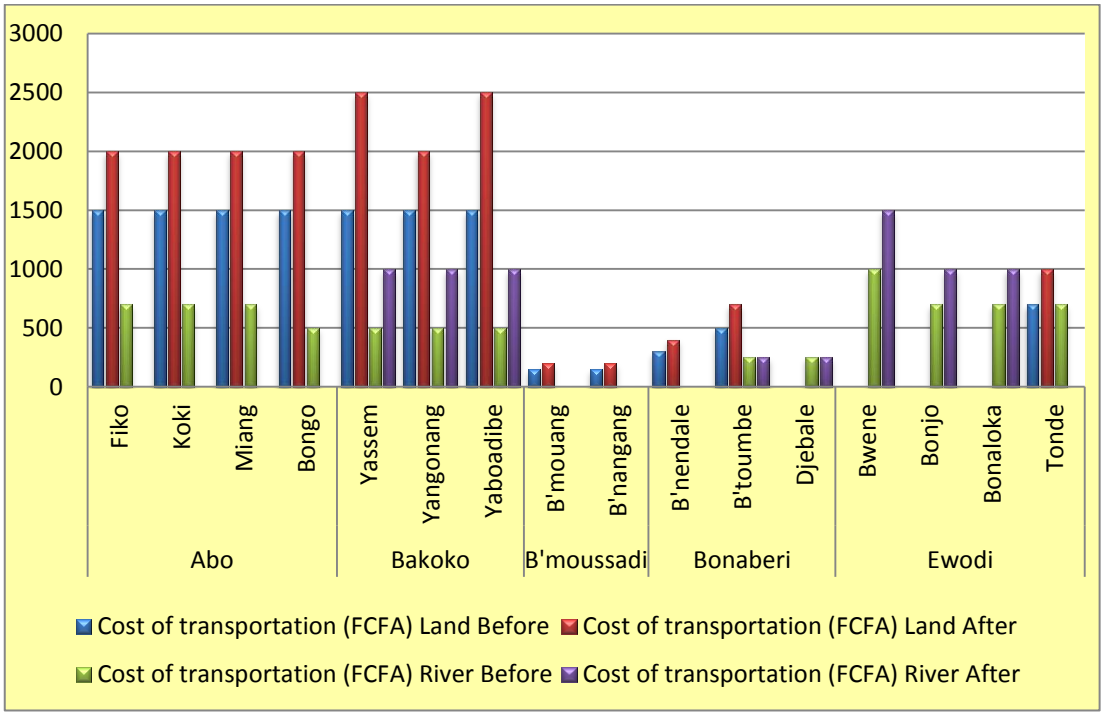


Figure 20: Transport costs from riparian villages to Douala by land and river before and after water hyacinth became a menace

Furthermore, although the time spent by land to Douala reduced due to the partial tarring of the road, the cost of transportation by land increased (Table 9). This is partly because more people travelled by land due to blockage of the main creeks by water hyacinth and partly due to general increase in fuel cost in the country. The Bonamoussadi communities never used the river for transportation because they are already in the city. Island communities like Bwene, Bonjo and Djebale, together with Bonaloka have always solely relied on the river for transportation to other villages as well as to Douala. The slight increase in the cost of transportation by land for the Bonamoussadi and Bonaberi areas excluding Djebale is due to increase in cost of fuel in the country.

4.4.2 – Impact on minor economic activities

Hunting: This is another activity which is affected by water hyacinth infestation, especially in Bwene, where one of the main creeks is completely blocked by water hyacinth. This was where hunting of sea animals such as crocodiles was being carried out. Also, most of their hunting sites for terrestrial animals are found across the river; hence, they have to paddle through the water hyacinth mats to get to these sites, which is very strenuous. However, the frequency of this activity has increased (Table 10) due to the fact that many fishermen abandoned fishing because of water hyacinth. They cope with this by cutting the water hyacinth to pave their way. Those who do not need to cross the river to carry out this activity have increased their number of traps to maximize their catch. The animals hunted on land include antelope, deer, "bush pig" and monkey.

Farming: Farming was mostly on a subsistence level before the arrival of water hyacinth. Some farmers, who were mostly women, had farm lands across the river. However, farming was affected in a similar manner as hunting. The farmers now have to paddle through the water hyacinth mats to get to their farms. Such farmers from the Abo and Ewodi areas are mostly affected because of complete blockage of their creeks. Sometimes these farmers had to cut the water hyacinth mats to pave their way through the river, which took time and caused fatigue even before they arrived at their farms. On the other hand, those whose farm lands were within the settlement area were not affected. Therefore, men had to join the women on the farms and the frequency of the farming activity within the settlement area increased after water hyacinth became a menace (Table 10). They began producing more food stuff than before, but they could not get much income from farming because, in addition to the fact that farming is seasonal, there was no way to carry their produce to the market through the river. In addition, getting to the markets by land is very expensive. Consequently, whenever they had excess food stuff, they sold some to neighbouring villages at a cheap price. The types of food stuff produced around the Wouri River include cassava, cocoyam, plantain, palm nut, okro, tomatoes and

pepper. In some of these villages, cassava is used to produce garri and *miondo*, while palm nut is used to produce palm oil, which are all sold.

Palm wine Tapping: This is another economic activity carried out by the riparian communities in the Wouri River Basin. It is carried out more during the dry season (from November to March every year). Before the arrival of water hyacinth, it was being carried out in just for home consumption. However, the frequency of this activity also increased (Table 10) due to reduction in fishing activities caused by water hyacinth infestation. More people join this activity and the wine was produced in higher quantities. Some of the wine is consumed as it is, while some is converted to a locally distilled wine known in Cameroon as *Aforfor*, which is sold to city dwellers. Most of the raffia palms from where the wine is tapped are accessible both from land and from the river. Some tappers equally traverse the river to carry out tapping on the other side. However, getting to those raffia palms that are accessible by the river became very difficult due to water hyacinth infestation.

Figure 21: 120 Litres (6 jugs of 20 Litres each) of palm wine from two palm wine tappers at Fiko, just arriving from their tapping sites across the river on the 27th of August, 2012.
Photo by: Cho Mujingni Jenette, August 2012.

Furthermore, the Frequency of the major economic activities dropped significantly with the exception of sand extraction which is still carried out despite its inherent risks. This is because is it very lucrative and so the divers bear the risk. The minor economic activities subsequently boomed during water hyacinth infestation although access to these sites was inhibited by water hyacinth. The villagers coped with this

problem by regularly cutting the water hyacinth to pave their way and also carry out most of these activities within the settlement area.

Table 10: Frequency of major and minor economic activities carried out by men before and after water hyacinth became a menace

Activities		Average frequency (days per week)	
		Before	**After**
Major	Fishing	7	2
	Sand Extraction	6	6
	Transport	7	2
Minor	Hunting	2	6
	Farming	1	6
	Palm Wine tapping	2	7

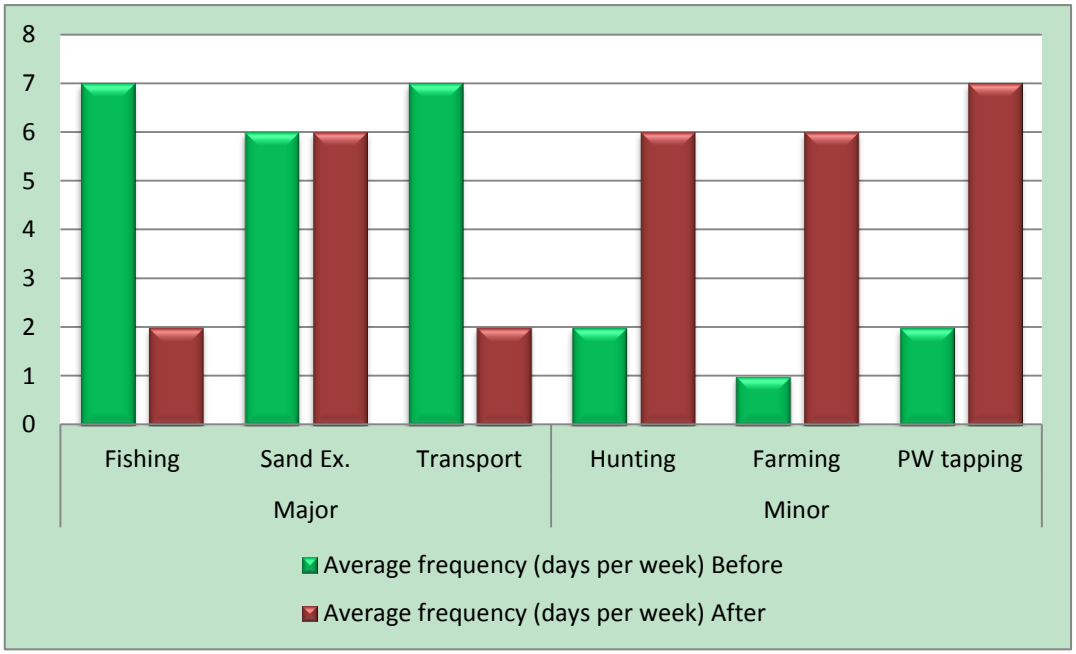


Figure 22: Frequency of major and minor economic activities carried out by the riparian communities before and after water hyacinth became a menace

4.4.3 - Social impacts

The most common social impact of water hyacinth in this area is on their recreational activities, notably canoe race and swimming, health problems and rural exodus.

Recreational activities: The majority of these villages used to participate in the canoe race usually organized during the "*Ngondo*" festival every month of December and win prizes. To participate, the tribes needed to carry out regular rehearsals during the year in preparation for the competition. The villages win money, gifts and fame; hence the competition is very important to them. However, with water hyacinth infestation, the size of the river has reduced in some areas and is blocked in others, making these rehearsals impossible. Consequently most of these villages have withdrawn from these canoe race competitions since water hyacinth became a menace in this river. Another consequence of the water hyacinth infestation is that, swimming competitions which were organized between the youths within the villages and between the youths of other villages and prizes won, are no longer possible.

Reduction in water quality: It was observed that the colour of the water was dark brown, especially in the Abo and Ewodi areas due to debris from dead water hyacinth. This is a main problem for the inhabitants since some of them still use this water for bathing and laundry. Portable water has been installed since 2009; hence, most of the villages no longer drink from the river. However, the 3 inhabitants of Bongo village still drink from a small stream in the village.

Health: The water hyacinth mats provide breeding grounds for disease-carrying vectors like mosquitoes which cause malaria and snails which cause bilharzia (shistosomiasis or snail fever) and mosquitoes which cause lymphatic filariasis (Buzzle, 2011; Calvert, 2002). Also due to the fact that water hyacinth reduces the quality of water which is the main source for drinking for some of the communities, there is the possibility of prevalence of other diseases like typhoid fever. Statistics from the Regional Delegation of Public Health, Littoral region show that the prevalence of these diseases had been on a rise even before water hyacinth became a menace (between 1997 and 2000). However, it continued to rise when water hyacinth became a menace from 2004 to around 2009 when the Ministry of Public health took measures to curb these diseases throughout the national territory. Firstly, impregnated mosquito nets were distributed to every household in the region and

secondly Mectizan for filaria was distributed free to every citizen. Similarly, because of lack of clean portable water in the region, a Chinese company was contracted by the government to connect portable water from the Moungo River for distribution throughout the city of Douala. All these measures contributed to the decrease in the prevalence of these diseases. However, the control of water hyacinth was not taken into consideration which could be another measure to reduce the prevalence of these diseases especially malaria, since these communities reported high concentration of mosquitoes in the infested areas. The villagers also confessed that their encounters with snakes become more frequent as the water hyacinth mats get denser. However, there have not been any cases of snake bites for a very long time because the snakes are killed whenever they are seen.

Table 11: Prevalence of diseases related to water hyacinth infestation in the sampled sub-division during the study period.

Diseases	**Malaria**						**Typhoid**					
	A	**D**	**Y**	**D.I**	**D. IV**	**D.V**	**A**	**D**	**Y**	**D.I**	**D. IV**	**D.V**
1997	300	100	150	400	500	600	400	200	150	200	202	100
1998	300	100	140	400	600	700	420	300	208	206	205	150
1999	200	155	150	250	650	600	410	200	150	201	205	170
2009	90	70	90	50	40	150	100	201	100	190	250	100
2010	100	150	10	30	70	80	70	80	60	71	90	80
2011	90	100	15	45	60	91	80	98	25	25	75	95
TOTAL	1080	675	555	1175	1920	2221	1480	1079	693	893	1027	695
Diseases	**Filaria**						**Schistosomiasis**					
	A	**D**	**Y**	**D.I**	**D. IV**	**D.V**	**A**	**D**	**Y**	**D.I**	**D. IV**	**D.V**
1997	80	30	40	80	200	70	100	255	200	300	400	50
1998	70	40	20	90	180	75	150	270	230	300	450	80
1999	65	30	25	91	190	76	150	270	230	310	450	81
2009	90	31	24	42	90	77	90	94	180	300	95	82
2010	95	40	50	25	80	30	90	70	65	80	51	30
2011	75	90	71	19	25	40	82	75	70	51	50	40
TOTAL	475	261	230	347	765	368	662	1034	975	1341	1496	363

Source: Regional Delgation of Public Health, Littoral Region, Cameroon.

A = Abo Sub-Division (Moungo Division)
D = Dibombari Sub-Division (Moungo Division)
Y = Yabassi Sub-Division (Nkam Division)
D.I = Douala I Sub-Division (Wouri Division)
D.II = Douala Iv Sub-Division (Wouri Division)
D.IV = Douala V Sub-Division (Wouri Division)

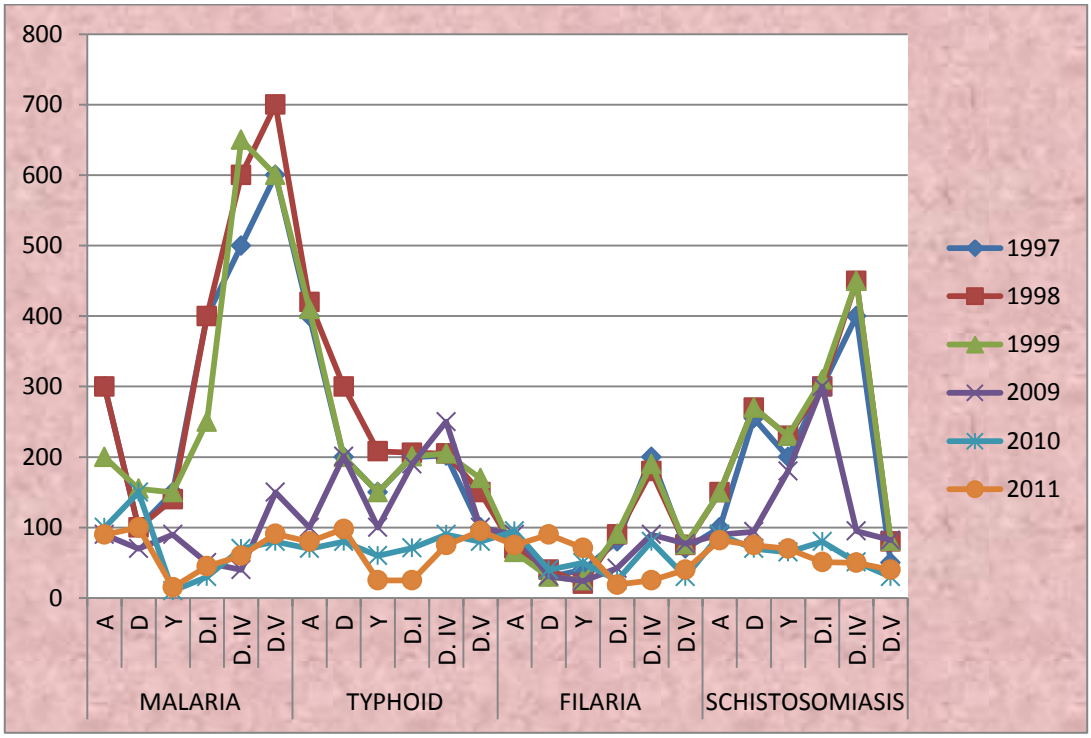


Figure 23: Trend in the prevalence of diseases related to water hyacinth infestation in the sampled sub-divisions during the study period.

Rural Exodus: Population statistics of the sampled villages show a drastic decrease in population over the study period, which according to them is mainly due to water hyacinth infestation (Table 12). The combination of economic, social and environmental pressures caused by the arrival of water hyacinth has undoubtedly meant increasing difficulties in surviving in the rural villages. This has contributed to the rural exodus. Some villages like Moussoko (See Figure 4, page 16) is totally extinct, others like Bongo is close to extinction with only 3 inhabitants left, while others like Yangounang has dropped drastically from about 200 inhabitants before the appearance of water hyacinth to 20 inhabitants today.

The case of Bongo is very interesting. Just like the people of Moussoko who have abandoned their village completely due to water hyacinth, this was same with the people of Bongo, who resisted to leave their village but discovered they had no choice than to abandon the village after water hyacinth completely blocked the Abo creek. This creek was and still is the only route to and from the village. Presently, only three people live in the village; 55 years old Mr. Emmanuel Mateke and his two

brothers; 35 and 30 years old. Bongo had a population of about 150 inhabitants who carried out only fishing, farming and sand extraction as their main economic activities.

Figure 24: Mr. Mateke Emmanuel and the writer (right), with 12 "Cameroun fish" (left) caught from the Abo Creek on the 28th of August 2012. The longest of the fish measured 88 cm in length.
Photo by: Cho Mujingni Jenette

According to Mr. Mateke, water hyacinth drove all the fish species except the so-called "Cameroon fish" (Figure 24). He manages to cope with water hyacinth by physical removal using his boat and cutlass. He cuts a portion of the river where he carries out his fishing, and repeats the process whenever the cut area became smaller again as the water hyacinth grew and reoccupied the portion. He sells Cameroun fish like the ones in figure 13 for about 3000FCFA (US$6) to 4000FCFA (US$8) each, depending on the size. The longest fish from his catch of that day measured 88cm long and cost 4000FCFA ($8US). According to him, this was his lucky day because he has not had such a catch for more than 8 months. Most often he gets nothing after casting his net. Due to the fact that he cannot have a huge catch to sell in the city, he sells some in neighbouring Yangonang and eats some. He also owns an orchard, where grapes, lime, banana and some other fruits grow. Apart from his economic problems, body itches, mosquitoes, low quality water (for bathing, laundry and drinking) are other problems he is facing in his village. Mr. Mateke keeps hoping that one day his village will be restored.

Table 12: Population statistics of the sampled villages before and after water hyacinth became a menace

Area	Villages	Estimated Population	
		Before	**After**
Abo	Fiko	100	26
	Koki	1000	250
	Miang	3000	2500
	Bongo	150	3
Ewodi	Bwene	500	300
	Bonjo	100	60
	Bonaloka	230	26
	Tonde	850	450
Bakoko	Yassem	250	150
	Yangonang	200	20
	Yaboadibe	300	150
	Moussoko	400	0
Bonaberi	Bonendale	1500	3000
	Bonamatoumbe	250	150
	Djebale	850	659
Bonamoussadi	Bonamouang	< 5000	> 7000
	Bonangang	< 3000	> 5000
Total			

Source: Interviewees (Appendix 1)

Statistics show that there is a drastic reduction in population of the sampled communities (Table 12). Bonamouang and Bonangang are villages in the Douala V sub-division, 5 km and 8km respectively from the heart of the city. Bonendale is also becoming an urban area with many people building in the village. Hence, apart from the indigenes of these villages, other people from all over the nation live there and work in Douala city. Majority of the villagers arguably moved to Douala and other cities in the Littoral region. This is reflected in the population statistics of these cities in the affected divisions to which the riparian communities belong. The population census carried out in Cameroon in 1976, 1987 and 2005 as well as predictions made in 1992 (Table 13) explains this situation and shows that Douala, which is the closest city to the riparian communities in the Wouri River Basin, has the highest population; hence, highest rate of urbanization.

Table 13: Population statistics of major cities in the littoral region

Years	1976	1987	1992	2005
Douala	458426	809852	1048915	1906962
Nkongsamba	70464	85420	93230	104050
Edea	25398	50609	69236	66581
Loum	26754	28465	29278	37537
Manjo	15434	19809	22189	26758
Mbanga	21422	24545	26111	28306
Melong	10776	16737	20445	49180
Njombe-Penja	25578	27182	16392	31090

Sources : http://www.citypopulation.de/Cameroon.html#Stadt_alpha
BUCREP, 2010

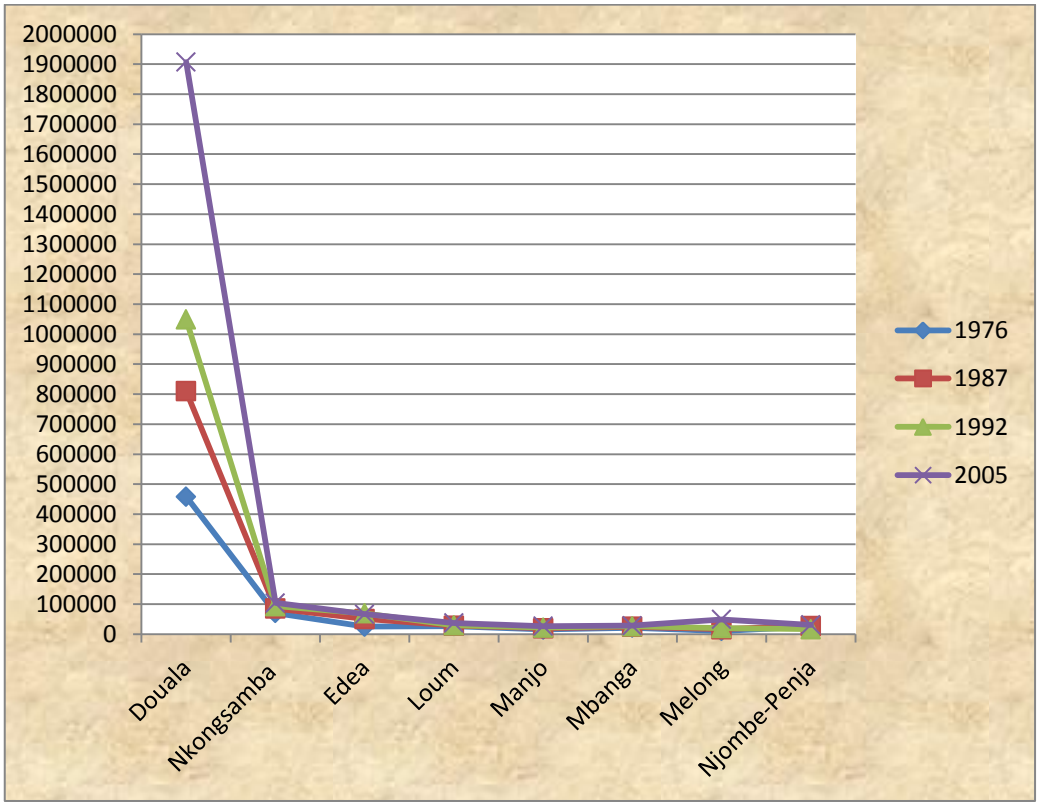


Figure 25 : Trend in population increase in the major cities in the Littoral region from 1976 to 2005

4.4.5 - Environmental impacts

The environmental impacts were not well perceived by the communities. However, from their description, the most common environmental impacts include; siltation, flooding, loss of biodiversity (disappearance and reduction in certain fish and plant species) as well as the appearance of new types of plant growing with water hyacinth.

4.5 - Conclusion

In conclusion, the assessment of the distribution of water hyacinth in the Wouri River Basin indicates that presently water hyacinth biomass is increasing at an alarming rate, with mats in already infested areas getting thicker and denser. Results from the survey on the quantification of the impacts on riparian communities also show that the villages upriver are most affected and most vulnerable to further impacts. However, if urgent measures are not taken to control the weed, the impacts will become severe downriver as well. This is because "islands" of water hyacinths cut off from the densely infested areas upriver, carried by waves downriver and where conditions are favourable they attach themselves to the banks and start proliferating.

The impacts of water hyacinth were generally well comprehended by the riparian communities except the environmental impacts. However, they classified the economic impacts to be more important than the other problems they face. Some social and economic impacts could be quantified but environmental impacts are not easy to quantify because they need research methodologies and techniques which were not available.

Various factors limited the extent of the research. They include time and financial constraints which prevented the writer from visiting all the riparian communities, the season (rainy season) and poor road network which made some areas inaccessible, high water tides which prevented the writer from going far up the river and in some cases, unwillingness to provide information by the inhabitants who reported that they are tired of providing information every time to researchers while nothing is being done to remedy the problem. Similarly, prolonged administrative procedures (bureaucracy) in offices prevented me from obtaining some useful information.

In the preceding chapters, a strategy has been proposed by the writer to urgently manage water hyacinth in the Wouri River Basin and some recommendations on measures to be taken to manage the weed to a level where it is no longer problematic.

Chapter five

Methods of water hyacinth control

5.1 - Chemical Control

According to the Agriculture and Consumer Protection Department of FAO, aquatic herbicides are a swift and effective technique for managing water hyacinth, in the case of severe infestation. The three most commonly used aquatic herbicides are: 2,4-D (2,4-dichlorophenoxy), Diquat (6,7-dihydrodipyridol) and Glyphosate. 2,4-D is a phenoxy herbicide and consists of ester derivatives of 2,4-dichlorophenoxyacetic acid. It is the world's most commonly used herbicide, being used for a wide range of agricultural and domestic purposes. It is often mixed with other active ingredients, as well as inert chemicals such as kerosine, which enables it to float on water (Lindsey & Hirt, 2000).

The diquat formulations are liquid bromide salts which cause a rapid inactivation of cells and cellular functions through release of oxidants (Gutiérrez, Huerto & Martinez, 1996). Glyphosate is an organophosphate, and is marketed most commonly under the names of Rodeo and Roundup. All these herbicides are absorbed through the leaves and are quickly transported throughout the whole plant, killing all parts of it (Lindsay, K. & Hirt, H., 2000).

Herbicide applications are usually less expensive than mechanical control but may have to be repeated on an annual basis (GISD, 2006); owing to the fact that once plants are removed, light penetration increases, favouring the germination of water hyacinth seeds and therefore new water hyacinth re-infestation. Estimated costs vary depending on size of treatment area, scale of treatment, and herbicide dosage. Costs per acre for materials and application by a licensed professional contractor are approximately $250 for glyphosate and may range from $700-1,000 for 2,4-D. (Gibbons, Rosenkranz, Gibbons Jr & Sytsma, 1999). In addition, human and ecosystem health have to be taken into account when aquatic herbicides are applied to water supplies (GISD, 2006).

5.2 - Biological Control

The biological control of water hyacinth began in the 1960s and involves control of water hyacinth through the use of host-specific insects, moths or pathogens which are natural enemies of the weed and imported from the point of origin of the weed (Deloach *et al.*, 1989). The weevils *Neochetina eichhorniae* Warner and *Neochetina bruchi* Hustache (Deloach & Cordo, 1976 a, b; Center *et al.* 1982) (Figure 26) are two species that have provided the best results for biological control. Marked successes with biological control agents have been reported from many parts of Africa and the world, notably at Lake Chivero, Zimbabwe (Chikwenhere & Phiri, 1999); Lake Victoria, Kenya (Ochiel *et al*., 1999); Louisiana, USA (Goyer & Stark, 1984); Mexico (Gutierrez *et al*., 1996), Papua New Guinea (Julien & Orapa, 1999) and Benin (Ajuonu *et al*., 2003; de Groote *et al*., 2003). Biological control remains the most cost-effective and environmentally friendly technique for the sustainable control of water hyacinth (Julien *et al*., 1996; van Wyk & van Wilgen, 2002; Julien, 2001)

Figure 26*: Neochetina bruchi* (left) and *Neochetina eichhorniae* (right) adults. Source: http://jandjaquafarms.com/weevil.htm

Other biological agents include the fungi *Alternaria eichhorniae* and *Cercospora piaropi* (Conway & Freeman, 1977; Martínez & Charudattan, 1998; Shabana *et al.* 1997) and the moths *Niphograpta albiguttalis* and *Xubida infusellus* (Julien et al., 2001). Results indicate that damage produced by fungus is enhanced when used in combination with insects (Charudattan, 1996; Galbraith, 1984, Martyn, 1985).

5.3 - Physical control

5.3.1 - Mechanical: Mechanical control refers to the use of machinery designed to physically cut, shear, shred, crush, press, lift or remove and transport aquatic plants

and associated organic material from water bodies (IFAS, 2012). Mechanical cutting and harvesting are practical for large-scale (several acres) vegetation removal because they remove plants from large areas in a relatively short time. Regrowth may occur within one month after cutting or harvesting; therefore several treatments per season may be required (WSDE, 2001). Mechanical control can be a temporal measure; however, it contributes to the spread of the weed because shredded bunches of the weed are carried by waves to other unaffected areas where they establish and start proliferating. Furthermore, mechanical harvesters are very expensive, risky and labour intensive to use. Estimated costs for harvesting range from $500-800 per acre, with additional costs for mobilization and equipment ($35,000-110,000) (WSDE, 2001) and there may be additional fees for disposal of plant material. Mechanical cutting and harvesting are non-selective and could eliminate valuable fish, plants and wildlife habitat within the target area. Additionally, research indicates that operation of mechanical harvesters can kill up to 25% of small fish in a given treatment area (WSDE, 2001).

5.3.2 - Manual removal: This involves the removal of water hyacinth plant by uprooting with hands or cutting with cutlasses. Manual removal, when carried out by many people at a time can reduce the weed. However, the method is very risky because of the existence of some animals such as snakes, alligators and crocodiles which live under water hyacinth mats. Furthermore, it is time consuming and labour intensive (May, Grosso & Collins, 2003) but if implemented systematically, it may be of great value to reduce a moderate stand of the weed (Labrada, 1995). Estimated costs for manual removal vary depending on the plant density and if volunteers will conduct removal. If divers and dive tenders need to be contracted, costs may range from $500-2,400 per day (Gibbons *et al*., 1999) and there may be additional fees for disposal of plant material (May *et al*., 2003).

5.4 - Integrated control

Integrated control involves the combination of two or more control methods to achieve weed reduction. Integrated management programmes are site-specific and

will depend greatly on the hydrological and nutrient status of the system, the extent of the infestation, the climate of the area and the use of the water body (Julien *et al*, 2001). This method has been a success in Tanzania where there has been a significant reduction in water hyacinth plant density, from 45 to 7 plants per 0.5 m^2 and the population by over 70% within a period of 3 years (Mallya et al, 2001). This was achieved mainly through biological control, manual removal, quarantine regulations and management of nutrient enrichment (Mallya et al, 2001).

5.5 - Industrial and local uses

Although water hyacinth is known by many as the world's worst aquatic weed, it has served as a source of income in some countries. Water hyacinth has been identified in many countries in the world to have the following uses:

5.5.1 - Paper: The Mennonite Central Committee of Bangladesh has been experimenting with paper production from water hyacinth for some years (Haider, 1989). They have established two projects that make paper from water hyacinth stems. The water hyacinth alone does not make a particularly good paper but when the fibre is blended with waste paper or jute the result is good (Calvert, 2002). The pulp is dosed with bleaching powder, calcium carbonate and sodium carbonate before being heated (Haider, 1989).

The first project involved relatively sophisticated equipment for pulping and the end product is of reasonable quality, while the second project uses a modified rice mill to produce the pulp. The quality of the paper is low and is used for making folders and boxes (Haider, 1989). Similar small-scale cottage industry papermaking projects have been successful in a number of countries including the Philippines, Indonesia and India (Ndimele, 2008 cited in Ndimele *et al*, 2011).

5.5.2 - Fibre board: Another application of water hyacinth is the production of fibreboards for a variety of end uses. The House and Building Research Institute in Dhaka has carried out experimental work on the production of fibre boards from water hyacinth fibre and other indigenous materials (Haider, 1989). According to Haider, 1989, chopped water hyacinth stalks are reduced by boiling and then washed

and beaten. The pulp is bleached and mixed with waste paper pulp and a filter agent such as china clay and the pH is balanced. The boards are floated in a vat on water and then finished in a hand press and hung to dry. The physical properties of the board are sufficiently good for use on indoor partition walls and ceilings.

5.5.3 - Yarn and rope: The fibre from the stems of the water hyacinth plant can be used to make rope. The stalk from the plant is shredded lengthways to expose the fibres and then left to dry for several days. The rope making process is similar to that of jute rope. The finished rope is used by a local furniture manufacturer who winds the rope around a cane frame to produce an elegant finished product (Haider, 1989).

5.5.4 - Baskets: In the Philippines water hyacinth is dried and used to make baskets and matting for domestic use (NAS, 1976 cited in Ndimele *et al*, 2011). The key to a good product is to ensure that the stalks are properly dried before being used. If the stalks still contain moisture, then this can cause the product to rot quite quickly. In India, water hyacinth is also used to produce similar goods for the tourist industry. Traditional basket making and weaving skills are used (Calvert, 2002).

5.5.5 - Charcoal briquetting: This is an idea which has been proposed in Kenya to deal with the rapidly expanding carpets of water hyacinth in Lake Victoria. The proposal is to develop a suitable technology for the briquetting of charcoal dust from the pyrolysis of water hyacinth. The project is still very much at the idea stage and both a technical and a socioeconomic study are planned to evaluate the prospects for such a project. However, although the technical aspects are yet to be tested, 7 main stages have been identified in the process of converting the plant into charcoal briquettes. These include harvesting and collection of the plant, drying, collection and transport to the kiln, pyrolysis, mixing of the resultant dust with a binder, pressing into briquettes and marketing of briquettes (Ndimele *et al*, 2001; Calvert, 2002).

5.5.6 - Biogas production: For many years, scientists have studied the possibility of converting water hyacinth to biogas (Ndimele 2008 cited in Ndimele *et al*, 2011). The process is one of anaerobic digestion which takes place in a reactor or digester

(an air tight container usually sited below ground) and the usable product is methane gas which can be used as fuel for cooking, lighting or for powering an engine to provide shaft power (Calvert, 2002).

The problems associated with the use of water hyacinth for digestion in a traditional digester is that water hyacinth has a very high water content of about 95%; therefore, harvesting effort yields a low reward in terms of organic matter for conversion to biogas (Ndimele et al, 2011). The digester size has to be large compared with that of a traditional type due to the low gas production to plant volume ratio, and this can in turn present problems for obtaining an airtight seal (Calvert, 2002).

5.5.7 - Water purification: Water hyacinth can be used to aid the process of purification of water either for drinking or for liquid effluent from sewage systems. According to Haider, 1989, water hyacinth has been used in a water treatment plant as part of the pre-treatment purification step, where clean, healthy plants are incorporated into water clarifiers and helped with the removal of small flocs that remain after initial coagulation and floc removal or settling. The result is a significant decrease in turbidity due to the removal of flocs and also slight reduction in organic matter in the water. Water hyacinth has also been used for the removal or reduction of nutrients, heavy metals, organic compounds and pathogens from water (Gopal, 1987).

5.5.8 - Animal fodder: Studies have shown that the nutrients in water hyacinth are available to ruminants. In southeast Asia, some non-ruminant animals are fed rations containing water hyacinth. In China pig farmers boil chopped water hyacinth with vegetable waste, rice bran, copra cake and salt to make a suitable feed. In Malysia fresh water hyacinth is cooked with rice bran and fishmeal and mixed with copra meal as feed for pigs, ducks and pond fish. Similar practices are much used in Indonesia, the Philippines and Thailand (NAS, 1976). The high water and mineral content mean that it is not suited to all animals.

5.5.9 - Agriculture: In agriculture, water hyacinth can be used on land either as a green manure or as compost (Lindsey & Hirt, 2000). As a green manure, it can be

either ploughed into the ground or used as mulch. After removing the plant from the water, it can be left to dry for a few days before being mixed with ash, soil and some animal manure (Lindsey & Hirt, 1999). Microbial decomposition breaks down the fats, lipids, proteins, sugars and starches. The mixture can be left in piles to compost, the warmer climate of tropical countries accelerating the process and producing rich pathogen free compost which can be applied directly to the soil. In developing countries where mineral fertiliser is expensive and soil quality is poor, it is an elegant solution to the problem of water hyacinth proliferation (Ndimele et al, 2011).

5.5.10 - Fish feed: The Chinese grass carp is a fast growing fish which eats aquatic plants. It grows at a tremendous rate and reaches sizes of up to 32 kg (NAS, 1979). It can eat both submerged and floating plants. The fish can be used for weed control and will eat up to 18 – 40% of its own body weight in a single day (Gopal, 1987). Also, dehydrated water hyacinth has been added to the diet of channel catfish fingerlings to increase their growth, hence used indirectly to feed fish (Gopal, 1987). According to Gopal, 1987 decay of water hyacinth after chemical control also releases nutrients which promote the growth of phytoplankton with subsequent increases in fish yield.

5.5.11 - Phytoremediation of heavy metals: The ability of water hyacinth to absorb heavy metals has been reported by many authors (Kumolu-Johnson et al., 2010; Ndimele & Jimoh, 2011; Ndimele, 2012). In the Ologe Lagoon, in Lagos, Nigeria for example, water hyacinth that was not deliberately introduced into the lagoon to absorb heavy metals did so even when the concentration of the heavy metals in the water column was very small (Ndimele & Jimoh, 2011). Therefore, although water hyacinth may have negative impacts on water quality, its ability to passively absorb heavy metals and nutrients can be put into good use (Ndimele, 2012).

Despite the wide range of uses of water hyacinth, the scope for large-scale utilisation of water hyacinth is limited because of the transport costs. Water hyacinth, containing more than 90% water, is very heavy and bulky to transport. Any larger-scale application must, therefore, be situated close to where water hyacinth grows.

5.6 - Strategy for the control of water hyacinth in the Wouri River Basin

The most important constrain to the fight against water hyacinth proliferation in Cameroon is the lack of a comprehensive strategy for the management of water hyacinth. The Wouri River Basin in particular has been a hot spot for years and several attempts to fight the weed have been unsuccessful. This writer therefore proposes a strategy for water hyacinth management in this river.

The responsibility for water hyacinth control should involve many people in an organized scheme. The strategy proposed by this writer is known as the PIIMEF strategy (Figure 27). In Cameroon, the responsibility for water hyacinth control should be organized by the Prime Minister, Head of Government, through an Order, designating the various ministries in charge of the management of water hyacinth, including authorities of the Port of Douala. The Heads of the ministries so designated in collaboration with heads of decentralized administrative units such as the governor of the region and authorities of the port should appoint representatives who should come together to establish a Water Hyacinth Management Committee (WHMC). The committee should hold meetings regularly and draw up a work programme. In consultation with stakeholders the appropriate methods to be included in an integrated management programme should be chosen. The choice of the methods chosen will be based on the level of infestation, knowledge of the weed's principal nursery sites, the effect of control on the environment and on major economic activities carried out in the river.

Biological control in combination with manual removal could be the most appropriate combination. According to Julien *et al,* 2001, biological control can provide the key component in any water hyacinth control programme. The aim of any biological control program is not to eradicate the weed, but to reduce its abundance to a level where it is no longer problematic. It offers a sustainable, environmentally friendly long-term control of water hyacinth.

A budget for the programme should be drawn and human, financial and material resources should be mobilized to achieve the goal. Human resources include

representatives from ministries, stakeholders (companies and NGOs), mayors of municipal councils, chiefs of the villages, experts with technical knowledge on the various control methods from Cameroon and other countries, GPS and GIS consultants, environmentalists and other services as the need arises.

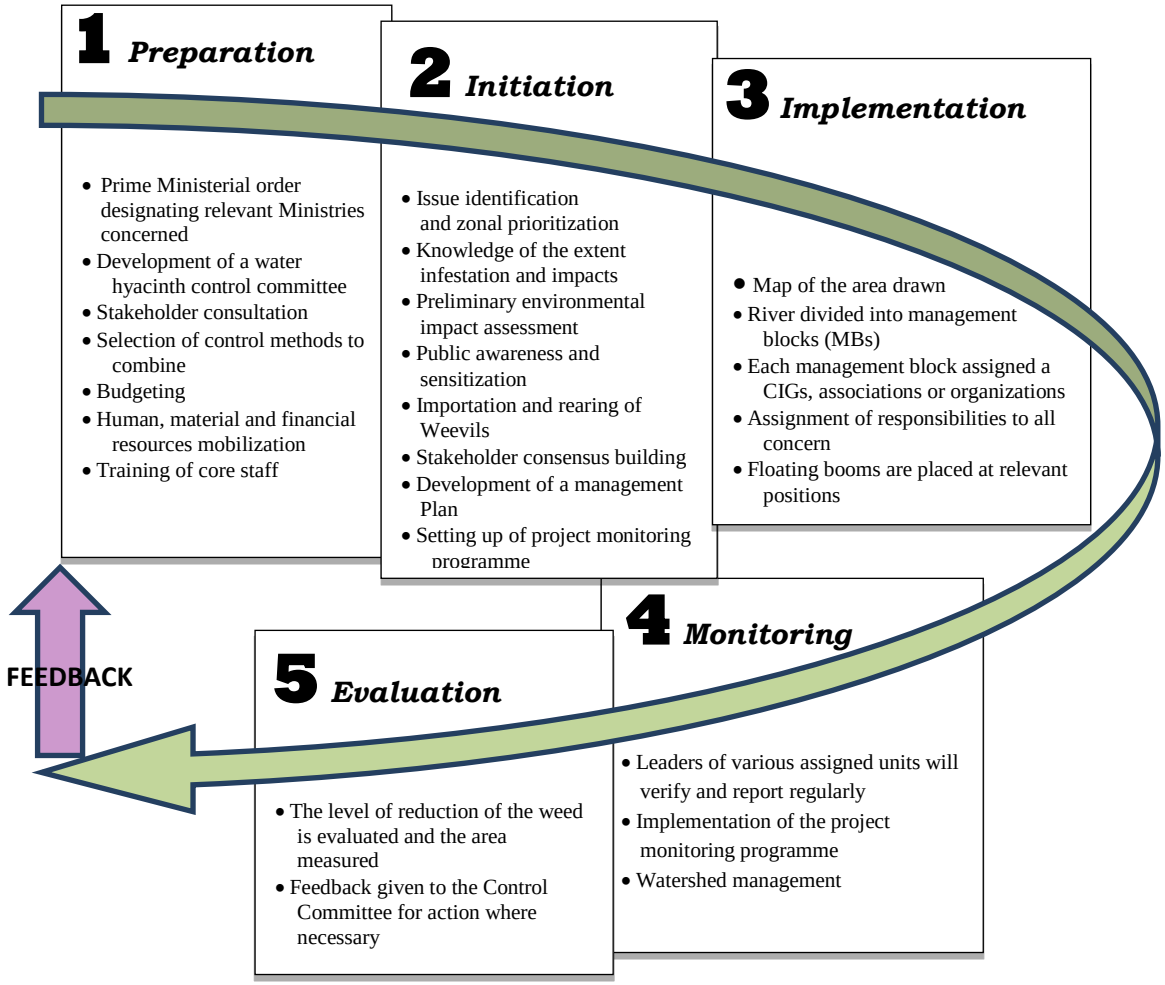


Figure 27: The PIIMEF strategy for the integrated control of water hyacinth in the Wouri River Basin
Source: Modified from Chua Thia-Eng, 2006.

Financial resource mobilization involves the lobbying for research grants from international organizations to supplement funds set aside by the government. Material resources involve the acquisition of all relevant materials that could be used, such as, *inter alia*, engine boats, importation of biological control agents and construction of their rearing sites, cutlasses, boots and floating booms. The core staff to carry out technical aspects of the project should be trained by experts and a general budget for the whole project should be developed. There already exist wide

experience and expertise available now in many countries; hence, technology could be purchased at a relatively low cost for effective and safe implementation of the programme.

At the initiation phase, water hyacinth distribution is studied either based on already existing mapping reports or a new mapping should be carried out to determine the highly and moderately infested areas as well as areas where only patches are present. Studies on the quantification of impacts such as the study made in this dissertation should be used to assess the extent of impacts on riparian communities. A preliminary environmental impact assessment should be carried out to know the impact of the chosen methods of control on biodiversity (flora and fauna) as well as on the riparian communities. Sensitization and public awareness programmes should be organized, such as workshops (seminars), campaigns, newspaper articles, radio and television programmes, such as documentaries on water hyacinth. A management plan should then be developed, clearly designating responsibilities. At this stage, a monitoring programme is also set up for monitoring after implementation.

Before biological control is carried out, potential agents should be identified and collected, detailed host-specificity tests should be carried out to determine their safety and a mass-rearing programme should be established to obtain large numbers for release. Before manual removal begins, a place where the water hyacinth will be dumped should be arranged. This could be an opportunity for those who wish to use it for agriculture as compost and mulch to get huge quantities for these purposes, otherwise, it is the opinion of this writer that pits could be dug at various areas along the river, where the water hyacinth could be dumped, covered with soil and allowed to rot. However, the handling of the weed after removal should be carefully supervised to avoid further spread.

To implement the management plan, a map of the Wouri River Basin should be drawn and the basin stratified into management blocks (Figure 28).

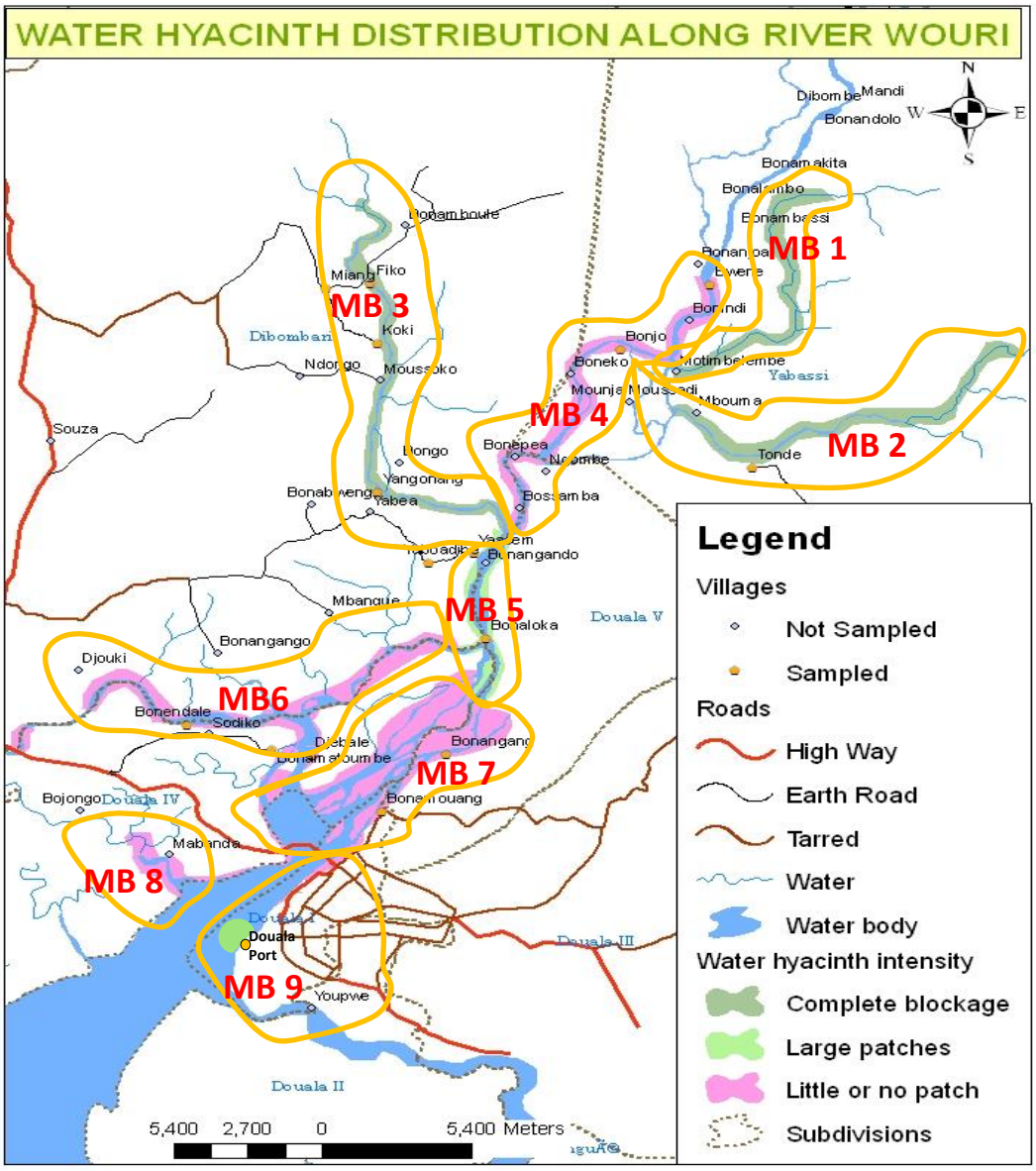


Figure 28: Management blocks (MBs) for Water hyacinth control in the Wouri River Basin

Floating booms should be used to block the mouths of MB1, MB2 and MB3 and biological control with *Neochetina* weevils carried out in these areas. This is the most favourable method here because it is heavily infested leading to complete blockage of these creeks. Manual removal should be carried out in MB4, MB5, MB6, MB7 and MB8. This is because firstly there are only patches in these areas (both large and small patches) and secondly this area is characterised by many economic activities notably fishing and sand extraction, which could be a hindrance to biological method. Furthermore, it is the main transport route to some villages upriver which are not accessible by land, for example Bwene.

In MB9, both biological and manual removal should be carried out because it contains mainly the Port of Douala where many quays have been severely infested by water hyacinth in some areas and large and small patches in other areas. The quay which is heavily affected is the fishing port, due to the presence of wrecks which had rendered a huge portion of the quay non-functional; hence, an opportunity for the proliferation of water hyacinth (Figure 29).

Figure 29: Water hyacinth at the Fishing Port in Douala
Photos by Wepandje Emmanuel, DAMVN Douala, 2009

Biological control should be most suitable in this portion. Other quays affected are UIC, CNIC and the Container Terminal which harbour large and small patches of water hyacinth (Figure 30). Here manual removal should be most favourable.

Figure 30: Water hyacinth infestation at the quays UIC (left) and Post 16 at the Container Terminal of the Douala Port (right)
Photos by Wepandje Emmanuel, DAMVN Douala, 2009

Further, the monitoring programme that was set up at the initiation phase should then be implemented. Each management units should be assigned to various groups for monitoring and reporting. Groups involved should include fishermen association, sand extractors association, CIGs and NGOs with each group having leaders. Leaders of groups assigned to particular MBs should work with their members to regularly verify and monitor the progress in weed reduction in their assigned blocks, and report to the WHMC. Groups should be made up of members who live close to their assigned management blocks for easy access and regular monitoring.

Finally, weed reduction should be evaluated at intervals of about 6 months. To do this, the quantity of water hyacinth removed every day from MBs should be weighed, recorded and documented before disposal. Another mapping should be carried out at the end of the programme to determine the area liberated of water hyacinth.

Feedback is an important part of the strategy which entails measuring the success and going back to the beginning to modify some flaws in the strategy. It could be a situation where the *Neochetina* weevils have not significantly reduced the weed. In such a situation, a third biological agent, which could be the moth known as *Niphograpta albiguttalis,* could be added to supplement the work done by the *Neochetina* weevils. It could also be a situation where the leaders of groups are not active, requiring a change. Corrective action should be taken on identified flaws for maximum success in the programme.

Chapter six

6.1 - Initiatives for water hyacinth management in Africa and the Middle East

6.1.1 - International initiatives

A lot of efforts have been made by some international organizations and research centres to provide technical support for initiatives geared towards the management of water hyacinth in Africa. Some of these include International Institute for Tropical Agriculture (IITA), the Commonwealth Scientific and Industrial Organization (CSIRO), the Centre for Agriculture and Biosciences International (CABI), the Food and Agricultural Organization of the United Nations (FAO) and the Commonwealth Science Council (CSC) (Navarro & Phiri, 2000).

Equally of significant importance in Africa and the Middle East is the International Development Research Centre (IDRC) through its Peoples Land and Water Program (PLaW) initiative. Through this initiative an information sharing mechanism was established. This mechanism was to foster and support timely decisions and efforts to control water hyacinth using regional capabilities which was regarded as the best immediate option to help improve the existing situation. An information partnership was then adopted by IDRC, known as Water Hyacinth Information Partnership (WHIP) through the PLaW initiative. WHIP constituted water hyacinth stakeholders and an information exchange and networking service. Its mission is to facilitate communication and the exchange of information on water hyacinth among affected people, decision-makers, experts and donors (Navarro, 2001). Through PLaW, many projects have been funded for the control of water hyacinth within Africa and the Middle East (Navarro, 2001). Unfortunately, Cameroon is not one of the countries that have benefited from this initiative.

6.1.2 - Regional initiatives

At the regional level, a few initiatives have been developed to improve response to water hyacinth. Worth noting is the ECOWAS Floating Weed Project. Due to the development of dense aquatic weed vegetation in West African water bodies, causing severe impacts on riparian communities, the Council of Ministers of ECOWAS

adopted, in 1987, a regional floating weed programme. This involved an integrated approach to weed management which includes the combination of biological and physical control methods (ADF, 2003). The broad objective of the project was to protect, rehabilitate and improve the biodiversity of water bodies in the region, with a view to conserving the environment (Phiri *et al*, 2000). It had six main components which included: a coordination of regional efforts to controls aquatic weed, integrated control of aquatic weeds on; the shoreline of Benin and Nigeria, the Niger river basin (also covering Benin and Nigeria), the upper Niger river (covering Mali), the Tano river (covering Côte d'Ivoire and Ghana) and the Senegal river basin (covering Senegal and Mauritania) (Phiri *et al*, 2000).

6.2.3 - National initiatives

National efforts for the management of water hyacinth proliferation in the Wouri River have been both at the administrative and local levels.

Administrative efforts: Ministries that have been involved in the management of water hyacinth in Cameroon include the Ministry of Transport, the Ministry of Environment and Protection of Nature (MINEP), the Ministry of Fisheries and Animal Husbandry (MINEPIA), the Ministry of Scientific Research (MINRESI) and the Territorial Administration (Councils).

The Watershed Task Group (WTG), an NGO in Cameroon, carried out studies and activities linked to the control and management of water hyacinth in the Wouri River in 2005 (Forpah, 2009). This study was supported by the International Union for Conservation of Nature - Netherlands (IUCN/NL) and the Education for Nature Programme of World Wildlife Fund US. This further lead to the organisation of an enlarged workshop in Douala on the 6th of January 2008 which was co-organized by PECTEN Cameroon Company LLC, the Douala City Council (CUD), Douala IV Urban Council, Global Water Partnership and Arts Bakery. Participants included various technical ministries in the Littoral region, universities, civil society organizations, local councils, arts and crafts men, youths and others, who shared their experiences (Forpah, 2009).

Furthermore, the Ministry of Transport, in 2007 had advertised tenders to study the problem and propose a method of management**.** Some companies submitted applications with proposals (AE/BTP, 2007). However, it was never executed**.**

Another seminar was organized from the 15th to 18th of September 2009, by the Ministry of Economic Planning and Regional Development (MINEPAT) in collaboration with the Ministry of Environment and Nature Protection (MINEP), the Ministry of Forestry and Wildlife (MINFOF), the Ministry of Transport (MINT), the Douala City Council (CUD) and others (Forpah, 2009). The aim of this workshop was to elaborate a national strategy for the control of the proliferation of water hyacinth (Forpah, 2009).

Local Efforts: Local efforts for the fight against water hyacinth has been geared towards the provision of space for carrying out certain activities such as bathing, laundry, fishing as well as access to farming and hunting areas. The villagers mainly cut and release the water hyacinth to be carried away by waves. This is done regularly by all the riparian villages in the Wouri River Basin. The people of Fiko, Miang and Koki who use the Abo creek for laundry and bathing often cut open small portions to make possible these activities. Some of the cut water hyacinth is either thrown on land allowed to dry or liberated in the water to be carried by waves.

Notably is the case of the Yassem village where their local effort to reduce this problem was encouraged by an NGO, the Watershed Task Group in collaboration with PECTEN, a petroleum company, who trained some of the villagers on the use of water hyacinth for the production of paper and fertilizers. Certificates were issued to them after the training and four engine boats of 15 horse power each were given to them with cutlasses. Work started after acquisition of these materials and a good portion of the weed was cut. However, they became discouraged by the fact that portions cleared of water hyacinth became fully covered again within the next two weeks, just as if nothing was done. To them it seemed as if the more they removed it, the more it grew again. It took twice a week on serious work to remove some quantity. Cutting became cumbersome and laborious, and it was finally abandoned.

On another occasion in this area, the superior Chief of the Yangonang village wrote to the government in 2005, requesting for aid in removing the water hyacinths, clearly stating the problems they were facing as a result of the infestation. There was no reaction on the part of the government. They developed their own initiative, by employing children to cut and release the weed in the water to be swept by waves. During that year, eleven young boys were employed on the 23rd, 26th, 30th of August and 2nd and 6th September to do the cutting and about 1000FCFA (US$ 2) was paid to each of them every day. They became tired due to lack of finance and the proliferation of the weed still continued. A second letter was written again in 2007, but there was still no answer. Another initiative was developed and a letter written to the Mayor of Dibombari to help the population. 1, 347,500FCFA (about US$ 2,645) was given to the population, which they used to acquire cutlasses, gloves, ropes, rented boats, produced CDs and motivated the workers. Workers came from Douala and cut the weed from Yassem to Yangonang so that the route to Douala from this village could be open to the villagers. Since 2007 nothing has been done again so the weed has rapidly grown and reoccupied the area.

The village of Tonde also organizes clean-up campaigns regularly where all the youths in the village are mobilized to cut the water hyacinth into pieces, allowing space for their socioeconomic activities and keeping their boat landing site open.

Apart from all these locally organized initiatives, individual fishermen also cut the water hyacinth regularly during their daily activities. This method has proven to be a short term measure since the liberated areas get infested again within very short periods. It also propagates the spread of the weed to other areas down the river where bunches of floating water hyacinths get attached at the banks and start proliferating.

Despite all these efforts to fight the proliferation of water hyacinth in the Wouri River Basin, its growth is still reported at an alarming rate.

6.2 - Constraints to water hyacinth management

Water hyacinth is spreading at an alarming rate in most countries across Africa and the Middle East. Despite the experience and expertise available in this region to deal with the weed on time, it is observed that the weed keeps on spreading, being a menace to the riparian communities of infested water bodies. Experts in Africa and the Middle East regions, under the auspices of the IDRC's PLaW initiative, investigated the constraints to water hyacinth management in the region (Navarro, 2001). They classified the constraints into three main groups, namely institutional, technical and financial.

The main institutional constraints, according to Navarro, 2001, are the most common and wide-spread, and are typical for developing financially poor countries. These have to do with problems of organization and bureaucracy across the many units within a country - sometimes even within one ministry - that deal with the weed. These units usually act without coordination or communication, often with different or conflicting objectives and with limited access to information and resources. Specifically, stakeholders identified the generally poor flow of information and the associated lack of timely access to such information by key decision-makers as the most critical constraints in need of immediate attention. Such information include, information on the spread and consequences of water hyacinth and on the available knowledge and expertise needed for early control as well as data on the socioeconomic impacts of water hyacinth and the basic facts about the weed that make it a problem and determine control options.

Also, the unnecessary bureaucracy of responsible institutions slows the initiation and implementation of programs for water hyacinth control and prevents the effective participation of riparian communities in campaigns to control the weed. Furthermore, most countries have no policy on water hyacinth which would designate the weed as a menace to water resources and spell out the need for urgent and effective control and management strategies.

Technical constraints to water hyacinth management include the lack of an appropriate integrated strategy for water hyacinth control in Africa. For this reason, countries in the region use the available control options merely as a series of tools to combat the weed, and their efforts have often been uncoordinated and largely ineffective. When combined with the institutional limitations, technical problems also include:

- Difficulties in identification of lead organizations with relevant structures to effectively coordinate control efforts and ensure the full participation of key stakeholders;
- Lack of regional efforts to ensure the collaboration and interaction of key players and the harmonization of efforts to control water hyacinth on a whole-catchment basis; and
- Lack of back-up services for techniques such as mechanical control.

Financial problems emanate from the very belief that efforts to control and manage water hyacinth are inadequately funded and not sustainable. This undermines efforts, even when governments and other agencies avail funds.

Of great significance to the fight against water hyacinth proliferation in Cameroon is the absence of a national strategy for the fight against water hyacinth. This has made many efforts unsuccessful since there is no coordinated programme stating clearly the role of each government department, stakeholders, municipal councils and local community involved in the fight. The end result is that funds allocated for this purpose get lost in the wind and very little work is done.

6.3 - Conclusion

Evidence suggests that the appellations given to water hyacinth as the world's worst aquatic weed or the "beautiful devil" is not an overstatement. Its proliferation in Africa as a whole and in Cameroon in particular has caused severe socioeconomic and environmental problems on riparian communities in many parts of the country including the Wouri River Basin. Economic activities such as fishing have come to a complete halt in some areas while it has reduced significantly in other areas. Furthermore, recreational activities such as boat racing and swimming have equally completely stopped in some areas and reduced drastically in others. The livelihood of close to 900000 inhabitants in the Wouri River Basin has been distorted, leading to social problems such as diseases prevalence and rural exodus. Some villages like Moussoko which had a population of about 400 inhabitants is completely extinct while others like Bongo is close to extinction, with only 3 inhabitants remaining.

Several attempts to manage the weed in this river have been limited to manual removal which has not been successful because removal is often uncoordinated and not done systematically with high labour force. Therefore portions liberated of the weed get covered again before another process of removal. By doing so this instead facilitates its spread because no barriers are often made to block the cut tufts from reaching other parts of the river. Some NGOs in Cameroon, notably the Watershed Task Group, have also encouraged its use in paper making, agriculture for production of compost and mulch and for making handicrafts. However, this has not yet proven to be sustainable. Also, because of the weight of tufts of the weed due to its water content, harvesting becomes very strenuous. Attempt to involve stake holders, villagers, municipal councils, administrative units and arts and craft men in the management has been successful only at the level of organization of workshops, but has not been successful practically because of lack of coordination and absence of a concise strategy.

It is therefore essential to adopt a holistic approach in an integrated management strategy such as that proposed by this writer, to manage the proliferation of water hyacinth in the Wouri River Basin.

6.4 - Recommendations

In addition to the comprehensive strategy, to be able to successfully manage water hyacinth in the Wouri River Basin and keep its abundance to a level that is no longer a problem, it is important for the following measures to be taken by decision-makers to avoid its further proliferation and re-infestation:

- There is the need for the government of Cameroon to develop a policy for water hyacinth, designating the weed as a menace to water resources and clearly stipulating the need for urgent and effective control and management strategies, wherever it occurs within the national territory.
- It is often said that prevention is better than cure. It is important to identify and map all the infested sites all over the national territory and take early action to manage it before it becomes problematic. Also in sites where control programmes are already established, once water hyacinth has reached a level which is no more problematic, it can then be brought under control through regular implementation of control programmes (e.g. biannually) since it is difficult to put a complete end to its proliferation because of the viability of its seeds.
- Good watershed management will help reduce the water hyacinth problem. High nutrient levels brought about by processes such as agricultural and urban waste promote the growth of water hyacinth. Therefore, industries around Wouri River should be inspected regularly to ensure the availability of proper sewage treatment and disposal plants. Also, farmers in the riparian communities should be discouraged from using fertilizers for agriculture which enrich the river through run-offs. Reducing nutrient inputs from these sources will slow down the growth and spread of the weed and further improve the effectiveness of control agents.
- Successes registered for integrated control in some regions like the Nseleni/Mposa Rivers and Lake Nsezi is largely because of community involvement (Jones, 2001). It is therefore vital to involve the riparian communities fully as well as some industries and urban communities who are end

users of the river. This is because they depend on the river resources directly for their livelihood and will therefor put in all efforts to protect it.

- Uncoordinated efforts to control water hyacinth on a water body by different parties individually have proven to be a waste of time and money. This is one of the reasons why water hyacinth management in the Wouri River Basin is unsuccessful. A holistic approach is therefore essential for sustainable management and maximum success in control programmes.
- Cameroon should join some regional initiatives such as the WHIP to share information about water hyacinth with other countries in Africa and the Middle East and learn from the experiences from countries which have succeeded in fighting the weed. A database of technical experts for the implementation of control methods like biological control could be obtained through WHIP, to assist in integrated control programmes in Cameroon.
- The government of Cameroon should establish cooperation ties with organizations such as IUCN through its Global Marine and Polar Programme, for constant advice on how to sustainably manage aquatic weed.
- The use of this weed should be discouraged because as Gopal, 1987 rightly said that "Developing countries should not encourage the propagation of this weed for utilization. The interests of humanity can only be safeguarded by seeking effective long-term control of water hyacinth, rather than by its utilization." The government could do this by providing alternative job opportunities to the users of the weed.

If all these measures are taken into consideration, water hyacinth which is presently a night mare to the riparian communities will become history, communities which had been disserted will regain their populations, socioeconomic activities will resume to normal and the livelihood of the riparian communities will be sustainable.

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APPENDIX 1

LIST OF INTERVIEWEES

Area	Village	Name of interviewees	Age / Gender	Village Title	Profession
Abo	Fiko	Anonymous Milango Hugo Anonymous	25 / F 19 / M 34 / M	- Youth President -	Farmer Farmer Farmer
	Koki	Anoymous (Refused to give names)	45 / M 27 / M 30 / M 17 / M 16 / M	Head of Village (King) - - - -	Fisherman/Farmer Fisherman Fisherman Fisherman Fisherman
	Miang	Ekolo Daniel Ekwalla Paul Mbangue Pierre Mbia N. Daniel	32 / M 48 / M 74 / M 65 / M	- - Notable -	Student Farmer Farmer Farmer
	Bongo	Mateke Emmanuel	55 / M	-	Fisherman
Bakoko	Yassem	Nsangue Felix Moukoko Paul Elangue Thomas Diboa Berthe	46 / M 55 / M 53 / M 38 / F	Youth President - - -	Fisherman Fisherman Fisherman Farmer
	Yangonang	Eboa Eyoum Esaie	75 / M	Secretary of village council	Former fisherman
	Yaboadibe	Ngille Edimo David	65 / M		Pastor
Ewodi	Bwene	Ekule Emmanuel (0023794085317) Bamo Leonard Nkote François Koto Bertrand Haiwadiwa Albert	52 / M 38 / M 34 / M 40 / M 20 / M	Secretary of village council Chief's messenger - - - -	Fisherman/ Farmer Farmer Farmer Farmer Farmer
	Bonjo	David Eboa Emile Njoue (0023793798498) Masso Jean Mangabelle	65 / M 50 / M 62 / M	Village head (Chief) Chief's messenger -	Farmer Fisherman Farmer
	Bonaloka	Helen Glasgow Famle Daniel Sunday Glasgow Dressman Peter Glasgow Kaemow Saturday Glasgow	25 / F 39 / M 32 / M 45 / M 77 / M 42 / M	- - - - Notable -	Fishing Fisherman Fisherman Fisherman Retired fisherman Fisherman
	Tonde	Ibrahim Saidou	26 / M	-	Farmer
Bonamou-ssadi	Bonamouang	Ndonfack Boniface (Ziko)	48 / M	Président d'Amical des depositaires d'agregats Bonamouang	Sand Extractor
	Bonangang	Njoh Yaka Philippe Mbonjo Frederic	62 / M 37 / M	President of Sand Extractors Ass. Executive member	Sand Extractor Sand Extractor

		Nsia Victor Ngando Epee Ebelle Monaudjo	39 / M 32 / M 42 / M	Executive member Executive member Executive member	Sand Extractor Sand Extractor Sand Extractor
Bonaberi	Bonamatoumbe	Matoumbe Kum Samuel Mrs Matoumbe	49 / M 35 / F	- -	Fisherman Gear maker Farmer
	Djebale	Diwsse Samuel Songue Jacque Moukillo Same	63 / M 46 / M 52 / M	Village head (Chief) Notable -	Fisherman Fisherman Fisherman
	Bonendale	anonymous	32 / M	-	Sand Extractor

Name	**Ministry / Department**	**Title**
Mr. Wepandje Emmanuel	Ministry of Transport / Department of Maritime Affairs and Inland Waterways (DAMVN) Douala	Chief of Service for Licensing and Controls (00237 77775293)
Mr. Emmanuel Gbe	Ministry of Fisheries and Animal Husbandry / Centre d'allevinage et de Contrôle des Pêches de Youpwé	Sub- divisional Delegate for Douala II
Mr. Bakabo Yankiua Dieudonné	Ministry of Fisheries and Animal Husbandry / Centre d'allevinage et de Contrôle des Pêches de Youpwé	Technicien des Pêches (0023776286044)
Total		

APPENDIX 2

INTERVIEWER'S GUIDE QUESTIONNAIRE

PART ONE

Respondent N° _____

1. Age : _____
2. Gender : _____
3. Occupation : _____
4. Residence : _____
5. Do you know the plant called Water Hyacinth?
6. What do you know about the plant?
7. When it first noticed in this area?
8. What kinds of activities were being carried out in the river before the appearance of the Water Hyacinth?
9. Which activities can no longer be carried out in the river due to the presence of Water Hyacinth?
10. How has this plant affected the use of this river?

A. Fishing

11. How many fishermen were there in this village before the appearance of the water hyacinth?
12. How many are there now?
13. Do you do fishing for commercial purposes? Or for home consumption?
14. How many kilograms of fish did you make daily when water hyacinth was absent?
15. How much was it sold then?
16. How many kilograms do you make now?
17. How much does it cost now?
18. Which kinds of fish do you usually catch before Water hyacinth appeared?
19. Which kinds of fish do you catch since water hyacinth appeared?
20. What type of boat do you use for fishing?
21. Which age group were mostly involved in fishing activities before water hyacinth appeared?
22. Which age group are mostly involved now?
23. Apart from fishing, are there other economic activities being carried out by the people of this village?
24. If yes, what are they?
25. About what percentage of the population is involved in other economic activities before water hyacinth appeared? and after water hyacinth appeared?
26. How does water hyacinth affect your fishing activities?
27. How much does fishing gear cost?
28. How many fishing gears did you buy a year when water hyacinth was absent?
29. How many do you buy a year now?
30. How many times in a week do you go for fishing before WH appeared and now?
31. How do you preserve your fish?
32. Do you still do fishing now? If no, what economic activity do you do now?

B. Sand extraction

33. Do you extract sand in this area?
34. How sand extractors are there in this village?
35. Which age groups are involved in sand extraction?

36. Why this age group?
37. What do you do with the sand?
38. How many days in a week do you go for sand extraction before water hyacinth came and now?
39. What quantities of sand do you usually extract a day when there was no water hyacinth? and when WH appeared?
40. How much do you sell a $6m^3$ boat of sand before and after the arrival of this plant?
41. How much is a trip of sand since 1997 and has the price increased or decreased? why?
42. How has the reduction in size of the stream due to the presence of water hyacinth affected your use for the river for transportation of sand?
43. What are the kinds of problems sand extractors face with the presence of water hyacinth when carrying out their activities?

C. Transportation

44. How often do you use this river for transportation?
45. How many people own boats used for transportation for commercial purposes?
46. Has this number been increasing/decreasing since 1997?Why?
47. What is being transported across the river?
    Fish Tourists School children Other
48. Do you use paddling or engine boats?
49. How much do you make for one trip when you transport People _Goods _Sand_Fish __Tourists __ School children _ other _
50. What is or are the difficulties faced by people displacing themselves in this river that has been invaded by this water hyacinth?
51. How much fuel do you use a day for transportation when water hyacinth was absent?
52. How much do you spend for fuel now? why?
53. How has the reduction in size of the stream due to the presence of water hyacinth affected your use for the river for transportation?
54. How many days in a week do you transport in this river when water hyacinth was not present and now?
55. How long does it take to go to Douala by land before 1997 and now?
56. How much did it cost before 1997? How much does it cost now?
57. How long does it take to go to Douala by the river when there was no water hyacinth?
58. How long does it take now? And why?
59. Which kind of boat do you use for transportation to Douala?
60. When using engine boat how much do you pay from this village to Douala?
61. Are there any other economic activities you carry out in this village? Which one?

D. Biodiversity

62. Which kind of fishes, prawns, animals, useful plants present in the river in this area?
63. Which kind disappeared with the appearance of water hyacinth?
64. Are there any plant species that have medicinal value?
65. Are they present in water hyacinth infested areas? Yes No
    No idea
66. Which plant species have disappeared since water hyacinth appeared?
67. Have you discovered any new plant that appeared in water hyacinth mats?

E. Water supply

68. What do you use this water for? Drinking…laundry….. bathing….Other uses……
69. What are the qualities of this water?

70. How clean was the water when water hyacinth was not there?
71. Do you treat the water before drinking?
72. How has the appearance of water hyacinth affected qualities of this water as drinking source?
73. How has the presence of this plant affected the laundry and bathing in this area?
74. How do you cope with the presence of water hyacinth when you want to bath or do laundry?
75. How do you treat the water for drinking? Boiling…..Filtering….Chemicals….Other methods
76. How much does it cost to treat the water for drinking in a month?
77. Are there mangroves in this area?
78. What do you use mangroves for? Wood for fuel…..aquaculture …….sell……Other uses …..
79. How much do you make a month from sales of mangroves as wood?
80. How has water hyacinths in these mangroves affected your use for it?
81. Have there been cases of floods in this area?
82. If yes, how often do you have floods in this area? what do you think is the cause?
83. How many households were affected?
84. Can you estimate the loss in monetary terms?

F. Tourism

85. Do tourists visit this area regularly?
86. Which season do tourists usually visit this area? Summer holiday…..dry season…..Rainy season Christmas season…….others ……
87. How many tourists visited this area monthly before WH appeared?
88. Which are the touristic potentials of this area? Canoe race…….site seeing…..Bird watching …. Swimming….. diving…….research……Others…….
89. What economic activities are affected by the presence or absence of tourists? Sales of fish….. transportation …… others
90. How does tourism affect the livelihood of the population of this area?

G. Recreational Activities

91. What kinds of recreational activities were being carried out in the water in this area before and after the arrival of this plant? Canoe race Swimming site seeing…….diving others
92. Do you raise income when you organize canoe races?
93. What cultural activities are being carried out in the river in this area and how are these activities important to the people of this village? Rituals…..cleansing ….Festivals…….. Importance ……

H. Health

94. What kinds of health problems are common with people in this area? Cholera malaria filarial….. typhoid ……. others ……
95. How has the appearance of water hyacinth affected the prevalence of these diseases? Increased Decreased no effect Deaths other effects ……
96. Are snakes and crocodiles common in the water in this area since water hyacinth appeared?
97. Were they common when there was no water hyacinth?
98. How frequent do you have cases attacks from these Snakes and crocodiles?
99. What are the consequences of these attacks?.....
100. How much does a complete treatment of these diseases cost? Cholera Typhoid, Malaria, Ameobiasis, Filaria, Snake bite, Crocodile attack?

I. Hunting/trapping

101. Do you have any hunters in this area?
102. How many hunters carry out this activity before WH appeared?
103. How many hunters are there now?
104. How often do you go for hunting before WH appeared and now?
105. Has hunting activity increased/decreased? Why?
106. How has this plant affected hunting activities in the community?
107. Do you cross this river to go for hunting?
108. How does water hyacinth disturb your hunting activities?
109. What is the amount that an average hunter could make in a month before and after the arrival of this plant?
110. How many days a week do you go for hunting before water hyacinth appeared and now?
111. According to you, which of the impacts of water hyacinth infestation most important/ serious? Social……Economic…..Environmental…….

J. Farming

112. Who are those who do farming in this area?
113. Where your farm lands found?
114. Do you cross the river to go to the farm?
115. Did you do farming before water hyacinth appeared in this area?
116. How does water hyacinth affect your farming activities now?
117. What kinds of food stuff do you cultivate here?
118. Can you compare the quantity you produced now and that produced when water hyacinth was not yet a menace?
119. Do you know that water hyacinth can be used as fertilizer?
120. Where do you sell your farm produce?
121. How many days in a week do you go to the farm when water hyacinth was not yet a menace and now?

K. Palm wine tapping

122. Who are those doing tapping in this area?
123. Do you know how many tappers were in this village when water hyacinth was no there?
124. How many are there now?
125. Where are your tapping sites found?
126. How does water hyacinth affect your tapping activity?
127. How do you manage the problem to be able to continue your activity?
128. What quantity could you produce a day when water hyacinth was absent and now?
129. How many days in a week do you go for palm wine tapping?

INTERVEWERS GUIDE QUESTIONNAIRE

PART II: Questions to specific individuals and institutions

General information about the villages (Question to the Head of the village)

- Location
- Population before water hyacinth appeared and population now.
- Major economic activities
- When did water hyacinth first appear?
- What kinds of recreational activities are being carried out in the river in this area? Canoe race, Swimming etc…
- Do you raise income when you organize canoe races?
- What cultural activities are being carried out in the water in this area and how are these activities important to the people of this village? Rituals, cleansing etc…

Regional Delegation of Environment and Protection of nature

1. How many plant species are present in the river Wouri basin?
2. Which are the plant species that have medicinal value?
3. Which plant species have disappeared since water hyacinth appeared?
4. Which plant species have appeared since the appearance of water hyacinth?
5. What has the Ministry of Environment done so far to fight the proliferation of this weed?
6. Is there any national policy for water hyacinth control in Cameroon?
7. Has any national strategy been established for the fight against water hyacinth proliferation in Cameroon?
8. What are the constraints to the fight against water hyacinth proliferation in the Wouri River?

Regional Delegation of livestock and fisheries

1. What kinds of fish are present in the Wouri River?
2. Has any of these species disappeared since 1997?
3. Has any of the species increased since 1997?
4. What has MINEPIA done so far to fight water hyacinth proliferation in the Wouri River?
5. What is the trend in the amount of fish caught since water hyacinth became a menace in this river?
6. What do you think is the cause of the increase/decrease?
7. Where does the fish sold in the fish market in Youpwe come from?

Central Bureau of Census and Population studies

1. Can I have the statistics of the villages around the Wouri River Basin during the 1976, 1987, 2005 and 2010 population census in Cameroon?
2. Has rural exodus affected the population trend in the urban and rural areas of the Littoral region?

District health centres

3. What kinds of health problems are common with people in the Wouri River Basin? Cholera, malaria, filarial, typhoid, Ameobic dysentery?
4. What are the statistics on the prevalence of filarial, malaria, cholera, typhoid, ameobiasis, snake bites since 1997?
5. Have there been any deaths as a result of these diseases or snake and crocodile bites?

Watershed Task Group

1. Can you tell me what you know about water hyacinth in the Wouri River?
2. When was water hyacinth first noticed in Cameroon and where?
3. Apart from Wouri River Basin, which are the other areas in Cameroon infested by water hyacinth?
4. Which other NGOs or individuals have been involved in water hyacinth control in the Wouri river?
5. What has been done so far?
6. Which International and Regional NGOs or Organizations have tried to control water hyacinth in Cameroon?
7. What do you think is the best method to manage water hyacinth proliferation in the Wouri River Basin.
8. Do you use water hyacinth? For what?
9. How do you harvest it?
10. How sustainable is its use?
11. What are the constraints to the fight against water hyacinth proliferation in river Wouri basin?

Ministry of Transport/ Department of Maritime Affairs and Inland Waterways

1. Can you tell me what you know about water hyacinth in the Wouri River?
2. What has the Ministry of Transport done to control water hyacinth since it became a menace in the Wouri River?
3. What are the constraints to the fight against water hyacinth proliferation in Wouri River Basin?
4. Which other Ministries have worked in collaboration with the Ministry of Transport to manage this weed?
5. What do you think is the best solution to fight the weed?

APPENDIX 3:

SOME FIELD STUDIES PICTURES

A - TYPES OF WATER HYACINTH

Water hyacinth with bulbous petiole found in Bonendale. This type in mostly found in areas where infestation is less dense

Water hyacinth with slender petiole found in Yassem and many other villages. This type in mostly found in areas where infestation is dense

B - FOCUS GROUP DISCUSSIONS AND INTERVIEWS

Figure 1: Focused group discussion with Sand extractors at the Bonangang sand depot in the Bonamoussadi area

Figure 2: Focused group discussion with Sand extractors at the Bonamouang sand depot in the Bonamoussadi area

Figure 3: Focused group discussion with a former fisherman but now farmer at Fiko village in the Abo area

Figure 4: Interview with Mr. Eboa Eyoum Esaie, Secretary of the village council at Yangonang village in the Abo area. He shows letters that had been sent to the Minister of Transport in 2005 and 2007 possing the problem of water hyacinth in the area.

Figure 5: Focused group discussion with the Chief of Bonjo village and his messanger in the Ewodi area

Figure 6: Interview with Mr. Nsangue Felix, president of the youths at Yassem village in the Bakoko area

C - SOME COMMUNITIES VISITED

Boat landing site at Tonde village in the Ewodi area. This portion of the *Moundja Moussadi* creek is cleared regularly by the villagers to keep their landing site open.

D - SOME IMPACTS OF WATER HYACINTH INFESTATION ON FISHING ACTIVITY

Figure —: Paddling boats abandoned by fishermen at Koki village (first), Yangonang village (second) and Yassem village (third) due to complete coverage of the Abo creek by water hyacinth, which was their main fishing site. Fishermen abandoned fishing for other minor economic activities like farming and hunting.

E - SOME IMPACTS OF WATER HYACINTH INFESTATION ON SAND EXTRACTION ACTIVITY

Water hyacinth hooks a boat at berth at the sand depot in Bonangang and in some instances, cuts the anchor rope and the boat is carried by waves.

Water hyacinth propelled this sand extraction boat and got it stuck in the mangroves.

Water hyacinth blocks a sand extractor as he approaches the sand depot at Bonangang with his sand.

Photos by: Cho Mujingni Jenette, August, 2012

F - SOME HIGHLY INFESTED AREAS

A creek at Bwene village (Ewodi area)

Fishing port in Douala

The Moundja Moussadi creek at Tonde (Ewodi area)

The Abo creek at Fiko (Abo area)

The Abo creek at Fiko (Abo area)

The boat landing site at Yassem (Bakoko area)