East African Scholars Journal of Agriculture and Life Sciences
Abbreviated Key Title: East African Scholars J Agri Life Sci
ISSN 2617-4472 (Print) | ISSN 2617-7277 (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-3 | Issue-8 | Aug-2020 | DOI:10.36349/easjals.2020.v03i08.004

Research Article

Assessment of Plants at the Lake Kivu Shoreline, From Bwindi Road/ Oil Station to Amsar Section, on the West Coast of Lake Kivu

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Article History
Received: 06.08.2020
Accepted: 23.08.2020
Published: 30.08.2020

Journal homepage:
http://www.easpublisher.com/easjals/

Quick Response Code

Abstract: The work on assessment of plants at the Lake Kivu shoreline, from Bwindi road /Oil Station to AMSAR section, on the west coast of Lake Kivu had an objective to assess plants at the Lake Kivu shoreline, from Bwindi road /Oil Station to AMSAR section: determine species encountered at the Lake Kivu shoreline, the major plant canopy and beds present in a body of water and the benefits of revegetation. The quota method and the survey technique for the reconnaissance of shoreline plants were used. The species were classified on the forest species (*Grevillea robusta, Pinus patula, Eucalyptus* spp, *Acacia mearnsii, Measopsis eminii*), the agroforestry species (*Vernonia amygdalina, Markhamia lutea Markhamia lutea, Eucalyptus spp, Senna siamea, Eurytrina especinica*), the ornamental species (*Caesalpinia cesalpinia, Spathodea campanulata, Terminalia mantaly, Casuarina equisetifolia*) and other (*Phragmites australis, Bambusa vulgaris, Eleocharis cellulose and E. interstincta*). The shoreline of Lake Kivu in this section should be revegetating for the protection and food of fish and other animal species. In addition, we propose that the sole use of aboveground biomass as a proxy for valuing coastal protection services should be reconsidered and South Kivu provincial authorities must have created a control and waste collection service on the Lake Kivu shoreline.

Keywords: Lake Kivu, emergent plant, wetland, land, shoreline.

INTRODUCTION

Plants are important to humans and all other animals including fish (Kawarazuka and Bene, 2011; Tacon and Metian, 2013). The role of plants in aquatic systems is significant. Aquatic plants provide valuable fish (USAID, 2016; Pauly and Zeller 2016) and wildlife habitat (Dibble *et al.*, 1996). It serves as a food source for waterfowl and other aquatic wildlife, improve water clarity and quality (James and Barko 1990). It reduces rates of shoreline erosion and sediment re-suspension (James and Barko 1995), and helps prevent the spread of nuisance exotic plants (Smart *et al.*, 1994). Additionally, Plants stabilize sediments, improve water clarity and add diversity to the shallow areas of lakes (Madsen, 2014).

Madsen (2014) shows plants that grow in littoral zones are divided into three groups: Emergent plants inhabit the shallowest water and are rooted in the sediment with their leaves extending above the water's surface. In fact, the representative species of emergent plants include bulrush, cattail and arrowhead. The floating-leaved plants grow at intermediate depths. Some floating-leaved species are rooted in the sediment, but others are free-floating with roots that hang unanchored in the water column. The leaves of floating-leaved plants float more or less flat on the surface of the water. Waterlily and spatterdock are floating-leaved species, whereas waterhyacinth and waterlettuce are free-floating plants. The submersed plants are rooted in the sediment and inhabit the deepest fringe of the littoral zone where light penetration is sufficient to support growth of the plant. They grow up through the water column and the growth of most submersed species occurs entirely within the water column, with no plant parts emerging from the water. Submersed species include *hydrilla*, curlyleaf pondweed, *egeria* and *vallisneria*.

Fish have an important socio-economic role for human communities living along tropical rivers and are a major protein source for these people (Oceanic Development, 2014; Santos *et al.*, 2014; The World Bank 2015; World Food Programme, 2015; Lobón-Cerviá *et al.*, 2015). Because the annual flood reduces the area available to agriculture, local farmers turn to fisheries to obtain income during the high-water season.

Lake Kivu (1460 m above sea level (asl)), the smallest of the African Great Rift lakes, lies on the border between the Democratic Republic of the Congo

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(DRC) and Rwanda, in the tectonically and volcanically active Western Branch (Albertine Rift) of the East African Rift System (EARS) (e.g., Ebinger, 1989; Furman, 2007). As first reported by Damas (1937), the lake is characterized by the presence of a large gas reservoir at depth >50–80 m that, as indicated by subsequent investigations (e.g., Schmitz and Kufferath, 1955; Capart, 1960), has a CO_2 (CH_4)-rich composition.

Despite ongoing deforestation in tropical areas, little information exists concerning its impact on tropical fish and fisheries. Several studies have addressed the relation between forest cover and stream fishes in tropical areas (Toham & Teugels, 1999; Bojsen & Barriga, 2002). Similar studies have not been done for large rivers, even though destruction of habitats supporting fish populations has been hypothesized to be an important factor affecting the long-term health or reproduction of fisheries. Studies of the relationship between plant cover and stream fish have reached inconsistent conclusions. Additionally, information on an importance of riparian vegetation isn't extensive, the roles of them in the fish reproduction at the Lake Kivu shoreline are poorly known.

The purpose of our study was to assess plants at the Lake Kivu shoreline, from Bwindi road/ Oil station to AMSAR section, on the west coast of Lake Kivu: determine species encountered at the Lake Kivu shoreline, Major plant canopy and beds present in a body of water and the benefits of revegetation.

METHODS

Area of study

The study was conducted at the Lake Kivu shoreline Bukavu-Goma raod exactly at the Bwindi road/Oil Station to Amsar section, on the west coast of Lake Kivu, in Bagira- Bukavu town and Bugobe-Kabare territory, province of South Kivu.

The west coast of Lake Kivu was selected for sampling along Bwindi/Oil Station to AMSAR (Association Momentané Safricas Ruvir) section because of selling fish at the lake shoreline. This road is in Bagira (Bukavu town) and Bugobe (Kabare territory) area in the province of South Kivu. Additionally, the lake was selected to include a range of size and type as well as a range of riparian vegetation covers.

Geographic location of Lake Kivu

According Holzförster and Schmidt(2007), Lake Kivu is located between 1 ^{O} 300 and 2 ^{O} 300S and 28 ^{O} 500 and 29 ^{O} 230E was formed in the Pleistocene, as a consequence of the intense volcanic activity of the Virunga Mountains, which dammed the Great Rift Valley and reversed the northward flow of the rivers in the valley. Presently, Lake Kivu's surface waters are maintained at an elevation of 1462–1463 masl by the Mururu hydroelectric plant near Bukavu (Figure 1). The waters are discharged toward south into the Ruzizi river and that enter Lake Tanganyika at a rate of 3, 2 km^3/a. The world's tenth-largest inland island, Idjwi, lies in the center of Lake Kivu and has a population of more than 100,000 DRC citizens and about 50,000 Rwandan refugees. The 1200 km long Lake Shoreline hosts several large cities and towns, including Bukavu, Kabare, Kalehe, Sake, and Goma in DRC and Gisenyi, Kibuye, and Cyangugu in Rwanda, with a total lakeside population of about 2,000,000. Lake Kivu has a total surface area of 2370 km^2 and a volume of 560 km^3 with a maximum depth of 485 m. Topographically, it consists of a large basin (Main basin) and four smaller basins (from north to south: Kabuno Bay, Kalehe, Ishungu, and Bukavu) (Figure 1), which are separated from the Main basin by sills of different depths presented on the figure 2 (Degens *et al.*, 1973; Tietze, 1978; Botz *et al.*, 1988; Spigel and Coulter, 1996; Lahmeyer International and OSAE, 1998).

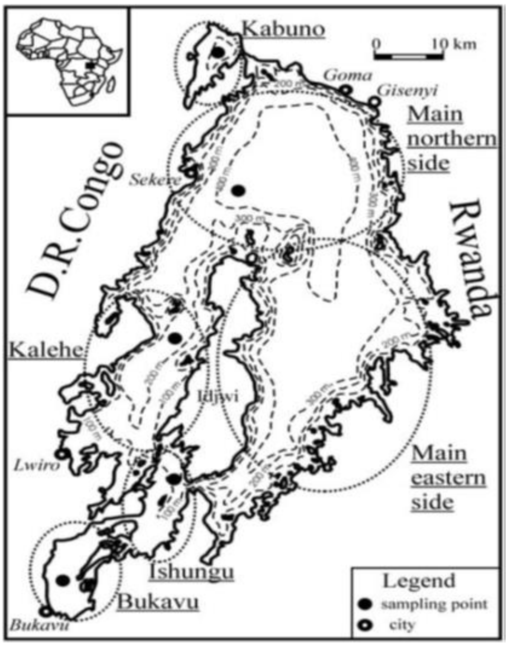


Figure1. Map of Lake Kivu with the location of the sampling sites (Tassi *et al.*,, 2009).

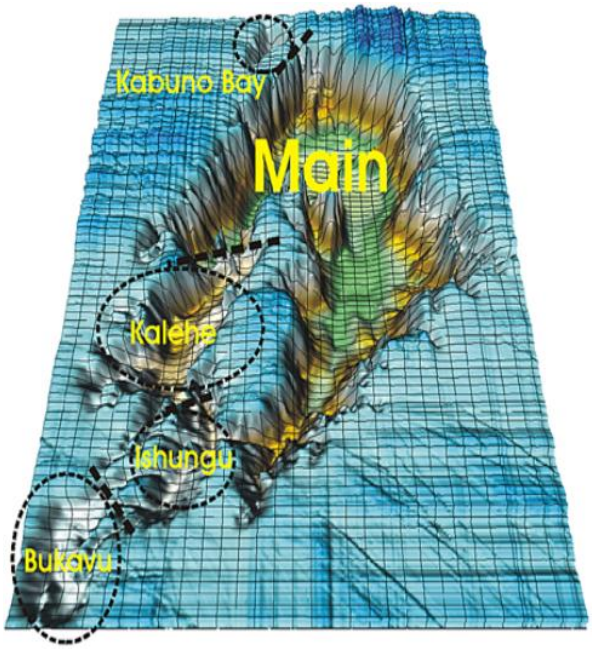


Figure 2.Three-dimensional bathymetric map of Lake Kivu (Tassi *et al.*,, 2009).

Data collection

Determination of Lake Kivu shoreline plant

Before four sites were chosen randomly on Bwindi road/oil station to AMSAR section (Bwindi/Oil Station-Trabemco, Trabemco-Ciel, Ketani-Murhundu-13 Km, 13 Km-AMSAR). Indeed, plants were observed at the Lake Kivu shoreline. Those plants were determined using photos proposed by National Forestry Agency, NAFA (2011), (Rodgers, 2002) and classified according to species types (forest, agroforestry, ornamental and other), scientific name, family and position (on land or emergent plant). The presence of species was represented per (*).

Reconnaissance survey

The reconnaissance survey is designed to identify the major plant beds present in a body of water. This is a qualitative survey designed to give an overview of the aquatic vegetation present in and / or at the edge of a lake. It identifies and documents problem areas that can be targeted when management practices are implemented. Each bed is given a reference number that is recorded on Tier I data sheets. When a major plant bed is identified, each species of plant found in that bed is recorded. Canopy ratings are given to each plant bed based on the types of plants present in that bed. The four major types of plants to be identified in this study are as follows: submersed plants, emergent plants, non-rooted floating plants, and rooted floating plants. The following scale is used to describe these four types of plants based on the percentage of the plant bed canopy they occupy:

- **Canopy Rating**

1 = <2% of canopy
2 = 2-20% of canopy
3 = 21-60% of canopy
4 = >60% of canopy

In addition to the canopy rating, another abundance rating is given to each individual species found in a particular plant bed. This abundance rating is based on the percentage of the entire bed area that species appears to occupy. The scale for this abundance rating is the same as the canopy rating scale. The difference is that this scale identifies the abundance of individual species in the bed:

- **Species Abundance Rating**

1 = < 2% of the bed
2 = 2-20% of the bed
3 = 21-60% of the bed
4 = >60% of the bed

Benefits of revegetation

The survey was done using quotas method. It consists to interview 100 fishermen's divided into groups of 25 fishers per site. Ten questions were asked and oriented on food source for wildlife, protective cover for small fish and other animals, source of nesting material for reptiles, birds, and small mammals, shade for fish and humans, erosion control and soil stabilization, aesthetics and landscaping appeal, animal attractor, nutrient uptake, plant competition for preventing encroachment of invasive species and living surface for small insects and other invertebrates important to fisheries. Survey data collected were analyzed using percentage calculation.

RESULTS AND DISCUSSION

Results

Table 1 shows the species, family, types of species and their position in the sites of the study environment.

Table 1. Species encountered at the Lake Kivu shoreline

Nº	Scientific name	Family	Sites					
01	*Phragmites australis*	Poaceae	other	wetland	*	*	*	*
02	*Eleocharis cellulose & E. interstincta*	Poaceae	other	wetland			*	
03	*Casuarina equisetifolia*	Casuarinaceae	ornament	land		*	*	*
04	*Bambusa vulgaris*	Poaceae	other	land			*	
05	*Terminalia mantaly*	Combretaceae	ornament	land			*	
06	*Spathodea campanulata*	Bignoniaceae	ornament	land	*		*	
07	*Eurytrina abyssinica*	Fabaceae	agroforestry	land			*	*
08	*Cedrela serreta*	Meliaceae	agroforestry	land	*	*	*	
09	*Mimosa scabrella*	Mimosaceae	forest	land		*	*	*
10	*Senna siamea*	Fabaceae	agroforestry	land		*	*	
11	*Measopsis eminii*	Rhamnaceae	forest	land			*	
12	*Acacia mearnsii*	Mimosaceae	forest	land		*	*	*
13	*Eucalyptus* spp	Myrtaceae	forest and agroforestry	land	*	*	*	*
14	*Markhamia lutea*	Bignoniaceae	agroforestry	land	*		*	*
15	*Pinus patula*	Pinaceae	forest	land		*	*	*
16	*Grevillea robusta*	Proteaceae	forest	land		*	*	*
17	*Vernonia amygdalina*	Asteraceae	agroforestry	land		*		
18	*Caesalpinia cesalpinia*	Fabaceae	ornament	land		*		

Legend: * Presence

Three species of families of Poaceae and Fabaceae, two of Mimosaceae and Bignoniaceae, one of Casuarinaceae, Combretaceae, Meliaceae, Rhamnaceae, Myrtaceae, Pinaceae, Proteaceae and Asteraceae have been observed along Lake Kivu. These trees are classified as forest species (*Grevillea robusta, Pinus patula, Eucalyptus* spp, *Acacia mearnsii, Measopsis eminii),* agroforestry species (*Vernonia amygdalina, Markhamia lutea Markhamia lutea, Eucalyptus spp, Senna siamea, Eurytrina especinica*) ornamental (*Caesalpinia cesalpinia, Spathodea campanulata, Terminalia mantaly, Casuarina equisetifolia*) and other (*Phragmites australis, Bambusa vulgaris, Eleocharis cellulose* and *E. interstincta*). Those trees are more abundant in the Ketani-Murhundu-13 km site followed by Trabemco-Ciel also by 13 km-AMSAR and Bwindi /Oil Station-Trabemco. 2 species of emergent plants were present *Phragmites* and *Eleocharis*(*Phragmites australis, Eleocharis cellulose* and *E. interstincta*).

The major plant beds present in a canopy and body of water is presented in the table 2.

Table 2. Major plant canopy and beds present in a body of water

		Sites			
		Bwindi/ Oil Station-Trabemco	**Trabemco-Ciel**	**Ketani-Murhundu**	**13 Km-AMSAR**
I	**Canopy rating**	< 2% of canopy	2-20% of canopy	>60% of canopy	21-60% of canopy
II	**Species abundance rating**	< 2% of the bed	2-20% of the bed	>60% of the bed	21-60% of the bed
1	*Phragmites australis*			>60% of the bed	
2	*Eleocharis cellulose & E. interstincta*		2-20% of the bed	>60% of the bed	21-60% of the bed
3	*Casuarina equisetifolia*			>60% of the bed	
4	*Bambusa vulgaris*			>60% of the bed	
5	*Terminalia mantaly*			>60% of the bed	
6	*Spathodea campanulata*	< 2% of the bed		>60% of the bed	21-60% of the bed
7	*Eurytrina abyssinica*			>60% of the bed	
8	*Cedrela serreta*	< 2% of the bed	2-20% of the bed	>60% of the bed	21-60% of the bed
9	*Mimosa scabrella*		2-20% of the bed	>60% of the bed	
10	*Senna siamea*		2-20% of the bed	>60% of the bed	
11	*Measopsis eminii*			>60% of the bed	21-60% of the bed
12	*Acacia mearnsii*		2-20% of the bed	>60% of the bed	21-60% of the bed
13	*Eucalyptus spp*	< 2% of the bed	2-20% of the bed	>60% of the bed	21-60% of the bed
14	*Markhamia lutea*	< 2% of the bed		>60% of the bed	21-60% of the bed
15	*Pinus patula*		2-20% of the bed	>60% of the bed	21-60% of the bed

16	*Grevillea robusta*	2-20% of the bed	>60% of the bed	21-60% of the bed
17	*Vernonia amygdalina*	2-20% of the bed		
18	*Ceslpinia cesalpinia*	2-20% of the bed		

According the canopies, Ketani-Murhundu site has more >60% following by 13 Km-AMSAR site 21-60% olso of the Trabemco-Ciel site 2-20% and Bwindi/ Oil Station-Trabemco site < 2%. Bwindi/ Oil Station-Trabemco site has less bed (< 2%),comparatively to Trabemco-Ciel in range of 2-20%), 13 Km-AMSAR(21-60%) and Ketani-Murhundu site more bed(>60%).

The following is a summary of the advantages of replanting a shoreline in table 3.

Table 3. Summary of the advantages of replanting a shoreline

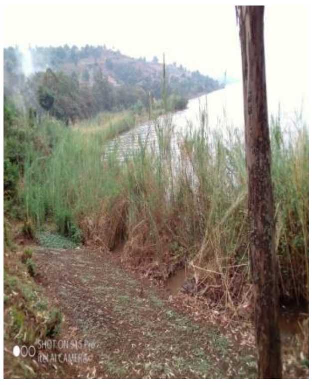
Benefits of revegetation	**Advantages of replanting a shoreline**
1. Food source for wildlife	20 %
2. Protective cover for small fish and other animals	23 %
3. Source of nesting material for reptiles, birds, and small mammals	21 %
4. Shade for fish (*Phragmites australis*) and humans (Bamboo)	8 %
5. Erosion control and soil stabilization	17 %
6. Aesthetics and landscaping appeal	2 %
7. Animal attractor	2 %
8. Nutrient uptake	1 %
9. Plant competition for preventing encroachment of invasive species such as hydrilla	2 %
10. Living surface for small insects and other invertebrates important to fisheries	4 %

23% of fishermen show the benefits of revegetation to be the protective cover for small fish and other animals as shown, 21% the source of nesting material for reptiles, birds and small mammals (Photo 1), 20% the food source for wildlife(Photo 2) , 17% erosion control and soil stabilization (Photo 3), 8% shade for fish and humans (Photo 4), 4% living area for small insects and other invertebrates important for fishing and respectively 2% the aesthetics and attractiveness of landscaping as well as competition from animal attractant plants to prevent the encroachment of invasive species such as hydrilla and 1% nutrient uptake.

(Photo 1)

(Photo 2)

(Photo 3)



(Photo 4)

DISCUSSION

Phragmites australis, Eleocharis cellulose and *E. interstincta* are emergents plants. The emergents can only occur in shallow water or damp soils along the shoreline and are unlikely to survive large changes in lake level (Mitchell, 1974; 1976). *Grevillea robusta, Pinus patula, Eucalyptus spp, Acacia mearnsii, Measopsis eminii, Vernonia amygdalina, Markhamia lutea Markhamia lutea, Eucalyptus* spp, *Senna siamea, Eurytrina especinica, Caesalpinia cesalpinia, Spathodea campanulata, Terminalia mantaly, Casuarina equisetifolia* founded on land are using as forest , agroforestry and ornamental species(Lamprecht, 1983; Moller , 1991; Doran and Turnbull,1997). The owners as organization non-governmental have cultivated a lush mixture of trees, shrubs and ferns along the shoreline. Shorelines are transition zones for both terrestrial and aquatic wildlife. It is especially important to have shoreline vegetation for rare species and for those species that need both aquatic and terrestrial habitat to complete their life cycles (turtles, many amphibians, and many birds). Wildlife needs travel corridors to move freely from one habitat to another. Vegetation along the shoreline shades and cools the water. In general, cooler water is better able to hold life-giving oxygen. Also, temperature spikes are detrimental to the health and reproductive rates of aquatic creatures (Budd *et al*., 1987; Swift, 1986; Stauffer and Best,1980; Welsch, 1991; Palmstrom, 1991; Phillips, 1989). Shoreline vegetation provides that last chance to capture pollutants traveling in stormwater (Massachusetts Vegetated Buffer Manual, 2003). Forested areas can capture, absorb and store 15 times more rainfall than grass or turf (Palone and Todd, 1998).

The influence of vegetation in sediment transport has been studied by several authors by means of field data. The effects of vegetation in minimizing erosion are roots hold surface soil and stabilize bank materials and it helps the ground to absorb water. It slows the velocity of runoff and traps sediment, absorbs the energy of falling rain and removes water from soil and transpires it into the air (shorestewards.wsu.edu, August 2020). Garcia and Duarte (2001) demonstrated that vegetation as *P. oceanica* fields decrease sediment erosion by reducing turbulence inside the meadow and restricting resuspension Recently, Christianen *et al.*, (2013) have highlighted the importance of the rhizoidal system in seabed stabilization. Several authors have considered the importance of vegetation mechanical properties. For example, Bouma *et al.,* (2005) showed the value of plant stiffness in wave attenuation by comparing the salt marsh *Spartina anglicawith* the seagrass *Z. noltii* and artificial vegetation made of different stiffness strips. All these studies clearly showed the importance of vegetation characteristics for their effect on hydrodynamic attenuation.

Our study showed Ketani-Murhundu and 13 Km-AMSAR sites has more canopies whereas; the Trabemco-Ciel and Bwindi/ Oil Station-Trabemco sites have less. According the bed, Bwindi/ Oil Station-Trabemco and Trabemco-Ciel sites have less, nevertheless, more bed for 13 Km-AMSAR (21-60%) and Ketani-Murhundu sites. The importance of the vegetation (trees, shrubs and ferns) as seagrass canopy for shoreline protection, our study on open, low-biomass and heavily grazed seagrass beds strongly suggests that belowground biomass also has a major effect on the immobilization of sediment. The presence of a short, low-biomass seagrass meadow maintains a higher bed level, attenuating waves before reaching the beach and hence lowering beach erosion rates (Christianen *et al.*, 2013; Bouma *et al.*, 2005). Even though, (Bos *et al.*, 2007) showed that eelgrass beds contribute to sediment deposition in intertidal habitats pointing out the influence of seasonal behavior.

The benefits of revegetation with native plants have been widely published:

The habitat benefits of shoreline, wetland, and stream buffers are also important. A narrow strip of trees and shrubs at the shoreline can create an important wildlife corridor that can provide food, water, and shelter for a variety of birds, amphibians, reptiles, and small mammals. A few species of aquatic plants are directly important to man for food and for materials used in building/constructions. The Indian rice, water chestnut and delta potatoes are sources of food. Some weeds (Nile cabbage, water spinach) are used as vegetable among many African communities. In some parts of the world, the bulrush is used for building boats, floor mats and wall partitions. The papyrus, *C. papyrus*, has been utilized for weaving baskets, making mats and thatching huts especially in rural communities (Prescott, 1969).

Limnologically, aquatic plants and shoreline vegetation play important roles including beach building, the filling in of lake margins with the accompanying aging and eutrophication and prevention of shore erosion. A few aquatic plants bring about the deposition of lime, thus, after a long period of time, produce useful marl deposits. Besides these, there are many interactions between aquatic plants, water chemistry and the nature of bottom deposits (Prescott, 1969).

Mitchell (1974) stated that the appearance of macrophytes in any aquatic ecosystem leads to an increase in the density of other plants and animal species. Therefore, two major effects of these weeds on the ecosystem are habitat diversification and food source for the organisms. Several studies using stable isotopes have reaffirmed plants, particularly aquatic plants (both C3 and C4 plants) as the main source of energy in most water bodies (Ojwang *et al.,* 2004; 2007). Macrophytes strands can act as a filter for excessive nutrients, which would otherwise lead to eutrophication of adjacent water bodies. Although the absorption may not in itself ensure the removal as the plants might re-release them on decomposition, the wet low oxygen soils favour denitrification by bacteria leading to loss of nutrients. The plants also remove heavy metals, biocides and other toxins from the water temporarily into their tissues. In theory, this could harm organisms higher up the food chain, however, the plants have various biological, chemical, biochemical and physical processes which immobilize, transform and fix the contaminants (Malthy, 1986). Factors that influence the establishment and distribution of aquatic plants include: depth, topography, types of substrate, exposure to currents and/or wind and water turbidity. The distribution of macrophytes is often related to their method of attachment (Sculthorpe, 1976). Aquatic plants, like most water organisms, are more widely distributed throughout the world than terrestrial plants. In Kenya, aquatic weeds were used to grace aquaria and ornamental ponds from where they escaped into natural or artificial water bodies causing serious problems (Njuguna, 1992). Macrophytes are among the most productive plant communities in the world (Sculthorpe, 1976) and are known to provide nutrition for humans and herbivorous animals. In general, water plants have both positive and negative importance to man, either directly and indirectly (Mitchell, 1974).

CONCLUSION

The results of this work show that the Trabemco-Ciel site and Bwindi/Oil Station-Trabemco site must be revegetated for the balance of nature on the shores of Lake Kivu. The benefits of revegetation are protective cover for small fish and other animals as shown, 21% the source of nesting material for reptiles, birds and small mammals, 20% the food source for wildlife, 17% erosion control and soil stabilization, 8 % shade for fish and humans as watches by fishermen. The authorities of the province of South Kivu must protect with plants and clean up the edge of Lake Kivu by creating a service in charge.

Acknowledgements

We would like to thank all the Authority of Research Centre in Natural Sciences. Thanks are also due to Agent of laboratory for the collect data for this study.

Compliance With Ethical Standards

Conflict of Interest:

We declare that there is no conflict of interest with the publication of this manuscript. No human/animal participants were involved in the preparation of this manuscript.

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