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Comparison of Macrophytes Distribution in Lake Hawassa at Different Pollution Entry Points, Hawassa in Ethiopia

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ABSTRACT

The aim of this experiment is the identification of the impacts of pollution on the Macrophytes species diversity, distribution and coverage in Lake Hawassa and their respective pollution sources. In doing so, rapid bioassessment method in five pollution entry points, where major socio-economic activities prevail around the lake is applied. Thirty six samples are taken, following three transect lines, approximately equidistant from one another, and from each sampling site, onshore, up to the end of the Macrophytes spreading into the lake, using rake. A total of 120 samples are collected and speciation is done using standard identification keys and photographs. Macrophytes coverage are approximated and different biotic indices are calculated for comparison between the sampling sites. The maximum distance of the Macrophytes is 200m and minimum is 30m. The minimum distance is recorded around Tikur Wuha (30-100m); the only river flowing into the lake and maximum is at Amora Gedel (80-200m), the fish market area. The five species of Macrophytes covering 8% of the lake named Paspalidium germinatum, Nymphaea caerulea, Typha angustifolia, Potamogeton schweinfurthii, and Cyperus exaltatus indicate that there is no invasive species like water hyacinth. The highest diversity is observed around Dore Bafano site and lowest is at Tikur Wuha. Even though there are no invasive Macrophytes species at this time, the disparity in diversity of the species supported at each specific site are an indication of the pollutants irregularly supporting the specific Macrophytes. It is better to stop the pollutants prospectively than trying to abandon the invasive species after their existence.
Keywords: *Pollutants, Macrophytes, Invasive Species*

INTRODUCTION

Freshwater Ecosystems have been critical to sustaining life and establishing civilizations throughout history (Small and Cohen, 1999). As indicated in Sudhira and Kumar (2000), storm water runoff and sewage discharges are the two common

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ways by which eutrophication and death of lakes happen (Dhote, 2007). Rapid population growth, urbanization, modern agriculture, poor infiltration when the adjacent land is concreted, commercial centers, garages, institutions and industrial development in the Hawassa City and its environs have posed potential risk to Lake Hawassa and its surroundings (Mulugeta, 2013).

Lake Hawassa, according to Kibret and Harrison (1989), in comparison to the other Rift Valley Lakes, has a relative high water transparency and low sediment load because the large swampy sites to the east on the Tikur Wuha River called Cheleleka acts as efficient settling sites for silt coming from the higher hills and mountains of the eastern escarpment (Vijverberg, Dejen, Getahun and Nagelkerke, 2012). At present, this wetland is completely dry (FfE, 2007). The surface of the Lake receives on average about 85 million m^3 of water annually through precipitation; however, the rate of open water evaporation on average is about 160 million m^3/year (FfE, 2007; Pattnaik, 2014). The loss of high amount of water through evaporation could be due to the extended coverage of Macrophytes which may enhance the process to evapo-transpiration. There are few data and information on trends of Macrophytes abundance and distribution in Lake Hawassa (Pattnaik, 2014).

The Lake supports extremely poor women and children, who have no other income sources to support their families. The water of the Lake is also used for bathing, recreation and as drinking water and other domestic uses, as well as for watering livestock and wildlife (Anasimos, 2013, Mulugeta, 2013). The fishery of the Lake supplies vital fish protein and incomes for the people of the sites and beyond. On the other hand, the trees of the relic forest around the Lake are inhabited by colorful birds chirping a lullaby with their mellifluous voice that titillate the hearts of people. Fishes dwelling in this Lake are food for the Plovers, Storks, Herons, Kingfishers and Fish Eagles (Mulugeta, 2013). Nowadays, the Lake Hawassa is seriously impinged by the various human activities in its watershed impacting water quality, storage capacity, recreational value, and natural lake bed habitat of natural and/or artificial lakes (Mulugeta, 2013).

Macrophytes are the common features of an aquatic ecosystem. Macrophytic vegetation plays an important role in maintaining the ecosystem of a lake (Dhote, 2007). Rooted Macrophytes serve as a living link between the sediment, water, and (sometimes) atmosphere in wetlands, lakes and rivers. The most notable function that plants serve is high primary production (Cronin, William, Lewis and Michael, 2006; Padial, Bini and Thomaz, 2008). Besides, Macrophytes are also involved in ecosystem processes such as bio-mineralization, transpiration, sedimentation, elemental cycling, materials transformations, and release of biogenic trace gases into the atmosphere (Cronin, William, Lewis, and Michael, 2006). The Macrophytes vegetation serves as shelter, hiding and resting sites, and breeding ground for weed bed fauna (Annelids, Crustaceans and Insects), protozoans, rotifers, cladocerans, copepods, ostracods and fish (Behailu, Bekele, Yosef, Kefyalew and Wondwossen, 2010). Macrophytes and in particular *Potamogeton schweinfurthii* is the major food for the grazing hippopotamus in the lake as well as it is a shelter for these large mammals and for the different reptiles residing at the littoral region of the lake (Behailu *et al*., 2010). On the other hand, it is important in curbing re-suspension of sediments and absorption of nutrients and toxic elements that have great impact on the lake water quality (Madsen, 2001).

The main threats to water quality in Africa include eutrophication, pollution, and the proliferation of invasive aquatic plants, such as the water hyacinth, which is attacking Lake Tana and Koka of Ethiopia currently as it did in different parts of the world (Ottichilo, 2003, Andersen, 2010). Hence, quantifying the Macrophytes coverage, distribution and diversity comparatively based on the adjacent socio-economic activities and identifying invasive species that could threaten the lake water quality and quantity is important to protect the lake. The main objective of this study is to identify the impact of pollutants on the Macrophytes diversity, distribution and coverage in the Lake Hawassa and their respective pollution sources. The specific objectives are:

i To quantify the coverage of Macrophytes in Lake Hawassa
ii To identity the species of Macrophytes in Lake Hawassa
iii To compare biometric indices in terms of the selected adjacent socio-economic activities

MATERIALS AND METHOD

Lake Hawassa took its name from the City named Hawassa, which is found at 270Km from the capital city of Addis Ababa in Ethiopia (Demelash, 2008). It is the smallest (96 km^2) of the eight major lakes found in the rift valley of Ethiopia (Mulugeta, 2013). The maximum depth of Lake Hawassa is 23.4m with an average depth of 11m. The major socio-economic activities adjacent to the lake are: the Fikir Hayk sites used mainly for recreation by food and drinking services; Amora Gedel sites, the major fish market place and storm water stabilization bond;

Referral Hospital sites where hospital waste accumulation pond, storm stabilization pond is found; Dore Bafano where the adjacent land is used for crop production and Tikur Wuha sites where the only river carries different types of discharges to the lake (Hawassa City Natural Resource Management and Environmental Protection Authority, 2015 unpublished report).

After receiving permission from the South Nations Nationalities and Peoples Regional State (SNNPRS) and Natural Resource Management and Environmental Protection Authority (NRMEPA) of the City, Rapid assessment of Macrophytes population in the five runoff entry points adjacent to the lake (Barbour, Gerritsen, Snyder and Stribling, 1999) following three equidistant transect lines perpendicular to the shore in the sites of interest (Fikir Hayk, Amora Gedel, Referral Hospital, and Dore Bafano) at three proportional spots per each transect. Each sampling spot provides composite of four pole-mounted rake (double rake head, 13.8 inch, with 14 teeth on each side) samples of Macrophytes collected on the four directions perpendicular to one another. Hence, 12 rake samples were collected from each transect and 36 rake samples were collected from each sampling site. After pulling the rake from bottom-up direction, those Macrophytes found in the sample were put in a plastic bag for identification and quantification offshore using standard keys and check lists. Macrophytes coverage was estimated by the interval between the longest and shortest transect lines at each sites and five key informants about the presence of gradual change on Macrophytes coverage overtime were asked.

The recorded data were averaged in their species category for each site and tabulated for comparison. In addition, diversity and similarity indices were calculated specifically for each species in the sampling sites and comparatively between sites to identify the variability between species composition, distribution enabling their difference indicating the impact of pollutants in the sampling sites. During data collection, trained data collectors were provided with rakes, meters, boats, hats, protective cloths, and life saving jacket, glove and first aid kits, log books, pens, markers, plastic bags, Global Positioning System and digital camera.

RESULTS AND DISCUSSION

Macrophytes coverage: The Macrophytes cover of the littoral zone stretched up to 200m (30–200m) (table 2). The overall Macrophytes cover decreased in the order of: Amora Gedel (80–200m) > Fikir Hayk (80–140m) > Referral Hospital (50–160m) > Dore Bafano (80–90m) > Tiku Wuha (30–100m). Preceding studies

(Tadesse, 2005; Behailu et al., 2010) on the Lake Hawassa found that the littoral sites extend out to 150m offshore and roughly follows the 4 m isobaths. Likewise, Amare (2005) indicates that the littoral zone of Lake Hawassa is fringed by an emergent and submerging Macrophytes belt that extends offshore down to 4m depth. By all appearances, the Macrophytes cover observed in this study reveals modest increment; even though the key informants say there is no change in the coverage and it is the water which is increasing on the littoral zone.

Taking a rough assumption of the 200m offshore distance of the Macrophytes coverage by assuming circular shape for the Lake (the lake have the longest distance of 16km and shortest 9km averaged to 12.5km diameter according to Mulugeta, 2013), the Macrophytes coverage could be calculated as:

$$\Pi\left(R^2 - r^2\right)$$

Where:

R is the radius of the lake (12.5/2km) and

r (200m = 0.2km) is the distance of Macrophytes from the shore.

Hence, Macrophytes coverage is approximately 39.1km^2 which is roughly 8% of the lake surface. This is very few when compared to Lake Tana (89%). Added up on the disappearance of Cheleleka Wetland (Yezbie, 2016), which was acting as a lung of the lake. Even though Macrophytes maintain the clear-water state by a variety of mechanisms (for example, stabilizing sediments, promoting zooplankton populations) (Cronin, William, Lewis and Michael, 2006; Padial, Bini and Thomaz, 2008), the water quality could not be maintained by the existing low coverage and few species.

Macrophytes species: The species identified over the five sampling stations were *Paspalidium germinatum*, *Nymphaea caerulea*, *Typha angustifolia*, *Potamogeton schweinfurthii* and *Cyperus exaltatus* (Table 2). All of the Macrophytes were emergent or floating; where none of them are submerged. Previous studies on lake Hawassa report that the littoral zone is covered with the various emergent, submerged and floating wetland flora including *Nymphaea caerulea*, *Potamogeton schweinfurthii*, *Typha angustifolia*, *Paspalidium germinatum* (Tadesse, 2005; Behailu *et al*., 2010; Pattnaik, 2014), *Cyperus exalatus* (Tadesse, 2005; Behailu *et al*., 2010) and *Ludwigia stolonifera* (Behailu *et al*., 2010; Pattnaik, 2014). Hence, there are no invasive species like water hyacinth in the Macrophytes species of the lake as it is not identified in this study, but the numbers of species are very few compared to Lake Tana, which comprises about 71 different species of Macrophytes (Yezbie, 2016).

Table 2 indicates that *Paspalidium germinatum* and *Nymphaea caerulea* are found in all the five stations while the other three Macrophytes (*Typha angustifolia, Potamogeton schweinfurthii* and *Cyperus exaltatus)* are recorded from only four sampling sites. On the other hand, *Paspalidium germinatum* is observed at every sub-station. The result is consistent with Behailu *et al*. (2010) who observe that *Paspalidium germinatum* is the dominant Macrophytes of the lake. Apart from this, *Potamogeton schweinfurthii*, *Typha angustifolia* and *Cyperus exaltatus* are absent in Amora Gedel, Tikur Wuha, and Referral Hospital stations. Hence, even though Amora Gedel site have large Macrophytes coverage, it does not hold true for the evenly distribution of each specie. The corresponding data on abundance presented in table 2 reveals that the most frequent *Paspalidium germinatum* is also the most dominant Macrophytes across the sampling stations. Besides, *Typha angustifolia* followed by *Potamogeton schweinfurthii* have considerable abundance over the three and two stations, respectively (Table 2). Apart from these, Behailu *et al*. (2010) find that the inflow sub-zone at the mouth of Tikur Wuha river has typical Macrophytes consisting of large patches of *Cyperus papyrus*, *Lemna minor*, *Wolffia arrhiza* and *Pistia stratiotes*.

Shannon diversity index and Evenness: Shannon diversity index, which characterizes biotic integrity and natural balance between flora and fauna without specifically diagnosing ecological conditions and causes of impairment (Barbour, Gerritsen, Snyder and Stribling, 1999) indicates that, the diversity index across the sampling stations range from the lowest value (H' = 0.53) at Tikur Wuha to highest value (H' = 1.25) at Dore Bafano (Table 3). But 89% of the species found in these sample sites are different from the calculated Sorenson's similarity index (Table 4) and the variation could be due to the few number of taxa (n = 5 from table 1) identified does not fulfill the minimum number of taxa recommended (n=10) by Barbour, Gerritsen, Snyder and Stribling, 1999. The variation observed between these extreme Shannon diversity index values are ascribed to their relative Richness between Tikur Wuha and Dore Bafano (R = 4 and 5 respectively) and Evenness (E = 0.38 and 0.78 respectively). Species richness is predicted to decrease with increasing pollution because many species are stressed (Barbour, Gerritsen, Snyder and Stribling, 1999), an indication of serious entry of pollutants on Tikur Wuha side of the lake; mainly by the Tikur Wuha river, which carry industrial effluents and other anthropogenic wastes (mainly organic in their origin according to Barbour, Gerritsen, Snyder and Stribling (1999). There is a substantial difference of diversity, Evenness on the shore lines of each sampling spot transect lines than at the middle and at the edge of the Macrophytes coverage (Table 3).

The analysis of the Macrophytes species with recourse to Sorenson index of similarity reveals that there are marked similarities (e” 0.75 or e” 75%) between the sampling stations (Table 4). Even though there is some diversity difference between Tikur Wuha and Dore Bafano, the difference arises only from the Evenness not from species Richness as indicated previously (Barbour, Gerritsen, Snyder and Stribling, 1999). This is also justified by species dissimilarity between Dore Bafano and Fikir Hayk (SR=5) while the Evenness is different (Table 4). This, in turn attributes to the absence of species like *Typha angustifolia* in Tikur Wuha, *Potamogeton schweinfurthii* in Amora Gedel and *Cyperus exaltatus* around Referral Hospital. This has determined the lesser similarity (75%) of these sites among themselves compared to the other sites. In line with the types and sources of pollutants, these sites are contributing a lot concentrated point source wastes from hospital and storm water stabilization bonds (Referral Hospital site), industrial wastes and wastes from different sources including the storm water entering into the lake carried by the only tributary called Tikur Wuha (at Tikur Wuha site) and wastes from the fish market, fish food processing houses, storm water stabilization pond (Amora Gedel site). While there is waste from the recreational sites of Fikir Hayk and the adjacent storm water accumulation artificial wet lands (Fikir Hayk site) and solely agricultural wastes from Dore Bafano Site.

Better Macrophytes diversity index indicates the relative health of the ecosystem at that specific site while specific species found in that site could infer some additional information for comparing the types of pollutants entering into the lake at each study site. *Typha angustifolia* does not prefer chemical pollutants like Cadmium and Lead (Klaudia, 2016); the reason it could be absent from the Tikur Wuha site and indicating not only the organic pollutants but also inorganic pollutants of anthropogenic origin is serious at this site.

Table 1: Macrophytes distribution in selected littoral sites of Lake Hawassa

Sampling sites	**Transect lines (m)**	
	Maximum	**Minimum**
Amora Gedel	80	200
Fikir Hayk	80	140
Tikur Wuha	30	100
Dore Bafano	80	90
Referral Hospital	50	160

Source: Experimentation, 2017

Table 2: Macrophytes composition, frequency of occurrence and abundance

Macrophytes species	Total		Fikir Hayk		Amora Dedel		Referral Hospital		Tikur Wuha		Dore Bafano	
	F	A	F	A	F	A	F	A	F	A	F	A
Paspalidium germinatum	100	296.4	100	93.3	100	75.7	100	61.0	100.0	142.7	100	121.3
Nymphaea caerulea	100	97.6	100	84.3	100	40.7	33.3	18.0	33.3	18.0	66.6	38.5
Typha angustifolia	80	117.5	33.3	101.0	66.6	43.0	66.6	24.5	0.0	0.0	100	78.0
Potamogeton schweinfurthii	80	71.3	33.3	9.0	0	0.0	100	40.7	66.6	25.0	100	34.7
Cyperus exaltatus	80	6.8	33.3	7.0	33.3	9.0	0	0.0	33.3	5.0	33.3	6.0

F = Frequency and A = Abundance; ***Source:*** Experimentation, 2017

Table 3: Diversity and Evenness of the Macrophytes

Shannon diversity	Fikir Hayk				AmoraGedel				Referral Hospital				Tikur Wuha				Dore Bafano			
index	T	S	M	En	T	S	M	En	T	S	M	En	T	S	M	En	T	S	M	En
H’	1.13	1.23	0.68	0.69	1.09	1.18	0.51	0.91	1.13	1.08	0.50	1.23	0.53	0.69	0.26	0.28	1.25	1.28	1.10	0.94
SE	0.70	0.76	0.98	1.00	0.79	0.85	0.79	0.83	0.81	0.98	0.72	0.89	0.38	0.63	0.37	0.40	0.78	0.80	0.79	0.85
SR	5	5	2	2	4	4	2	3	4	3	2	4	4	3	2	2	5	5	4	3

H’ = Shannon diversity index, SE = Species Evenness, SR = Species richness, T = total, S = shore, M = middle, En = end. ***Source:*** Experimentation, 2017

Table 4: Sorenson index of similarity and b-diversity of the Macrophytes

Sorenson diversity index		Sample sites comparison									
		Fikir Hayk-Amora Gedel	Fikir Hayk-Referral Hospital	Fikir Hayk-Tikur Wuha	Fikir Hayk-Dore Bafano	Amora Gedel-Referral Hsopital	Amora Gedel-Tikur Wuha	Amora Gedel-Dore Bafano	Referral Hospital-Tikur Wuha	Referral Hospital-Dore Bafano	Tikur Wuha-Dore Bafano
Index of	**A**	5	5	5	5	4	4	4	4	4	4
similarity	**B**	4	4	4	5	4	4	5	4	5	5
S=2C/A+B	**C**	4	4	4	5	3	3	4	3	4	4
	2C	8	8	8	10	6	6	8	6	8	8
	A+B	9	9	9	10	8	8	9	8	9	9
Similarity	**2C/A+B**	0.89	0.89	0.89	1.00	0.75	0.75	0.89	0.75	0.89	0.89

Source: Experimentation, 2017

CONCLUSION AND RECOMMENDATIONS

The Macrophytes coverage distance on the littoral zone of the lake is stretched up to 200m from the shore; indicating that there is some increment from the previous study. This could show that either the lake water level is decreasing or concentration of sediment is increasing. The total coverage of the Macrophytes is about 39.1Km^2; which is about 8% of the lake; this is very low compared to other lakes. It is maximum around Amora Gedel sites compared to the others; while least was at Tikur Wuha sites; which is further confirmed by the calculated diversity index at the same site and could be due to high inorganic and organic chemicals (from runoffs, industrial wastes, residential wastes, etc) entering the lake from the Tikur Wuha site through Tikur Wuha River. This can also be deduced from the characteristics of *Typha angustifolia* that does not like organic pollution and hence absent from this site. The Macrophytes were composed of five species namely *Nymphaea caerulea, Potamogeton schweinfurthii, Typha angustifolia, Paspalidium germinatum* and *Cyperus exaltatus;* which were very few compared to other lakes in Ethiopia. Even so, only two species *(Paspalidium germinatum* and *Nymphaea caerulea)* were common in all the sites while *Potamogeton schweinfurthii, Typha angustifolia* and *Cyperus exaltatus* were absent in Amora Gedel, Tikur Wuha, and Referral Hospital stations. *Paspalidium germinatum* was the most abundant Macrophytes in all the sampling sites.

The variation observed between these extreme Shannon diversity index values is ascribed to their relative species richness and evenness. There is greater organic pollution loads carried by the Tikur Wuha River when compared to other sample sites. On the other hand, all the sample sites have more than 75% Sorenson Similarity Index, which indicate that the impact of pollution between the sample sites is not that much different.

Generally, the few species identified and absence of invasive species that could seriously attack the lake is good; but their gradual increment in the distance they are covering could show that there is a danger attached to it. Hence, control of pollutants in these sites is very crucial; paying attention to Tikur Wuha sites and followed by Referral Haspital, Amora Gedel, Fikir Hayk and finally Dore Bafano. Even though there are no invasive Macrophytes species at this time, the disparity in diversity of the species supported at each specific site are an indication of the pollutants irregularly supporting the specific Macrophytes. It is better to stop the pollutants prospectively than trying to abandon the invasive species after their existence.

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