

Effects of Water Hyacinth on Fishery Resource and Its Expansion Trends in Ethiopian Water Bodies: A Review

Beshir Hussien¹ Bona Ali² Meseret Girma³

1.Oromia Agricultural Research Institute, Yabello Pastoral and Dryland Agriculture Research Center, P.O.Box 85, Yabello, Ethiopia

2.Arsi Zone Livestock Resource Development Office, Asella, Ethiopia

3.School of Animal and Range Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia

Executive Summary

Ethiopia is gifted with a variety of aquatic ecosystems. Aquatic ecosystems are often viewed as highly productive biological systems. At present Water hyacinth (*Eichhornia crassipes*) have been ranked as one of the world's worst invasive weeds causing problems to millions of users of water resources. The water hyacinth appeared in Ethiopia in 1965 at the Koka Reservoir and in the Awash River. Other infestations in the country include Gambela Region, the Blue Nile from just below Lake Tana into Sudan, Lake Ellen near Alem Tena and currently expanding to almost rift valley lakes. Assessment 2014 study shows that close to one-third or more than 30% of the shoreline of the north-eastern part of the Lake's shore is now invaded by water hyacinth. Under favorable conditions water hyacinth can double its mass every 5 days and it also grows from seed which can remain viable for 20 years or longer. Water hyacinth can also greatly affect fish catch rates, because mats of water hyacinth can block access to fishing grounds and clog eye of the net. Water hyacinth reduces fish stock for Tilapia and young Nile Perch by limiting access to breeding, nursing, and feeding grounds. Water hyacinth affects fish catchability especially when dissolved oxygen is reduced as a result of dense water hyacinth mats, this risk killing the fish. Access to sites becomes difficult when weed infestation is present, loss of fishing equipment. Further expansion of this plant will lead to drying up and shrinking of the lake. Depending on the degree of evapo-transpiration and the lake size, there would be completely dry-up and disappearance of the Lakes. As control measure several methods biological, physical chemical and integrated control approaches are under taken.

Keywords: Water hyacinth, Fishery, Expansion trends, Water bodies

DOI: 10.7176/JNSR/10-11-04

Publication date: June 30th 2020

1. INTRODUCTION

Ethiopia is a country having great geographic diversity. The topography varies and ranges from high peaks of 4,550m above sea level to a low depression of 110m below sea level. The predominant climate type is tropical monsoon, with temperate climate on the plateau and hot in low land areas. Usually highlands receive more and relatively stable rain fall than the lowlands. Ethiopia has great potential of both surface and ground water resources and result into giving a name to the country as the water tower of east Africa (Said,1993). The main source of water in the country is rainfall that results into having many trans-boundary rivers, which have different water volume in different seasons. This is factually true when one considers part of the country, particularly western, south western parts and the high land areas. (Seleshi B, 2007).

Aquatic ecosystems are often viewed as highly productive biological systems; they provide important resources for life and life management systems of mankind, such as water for consumption, fishing, irrigation, power generation, transportation and recreation. Ethiopia is gifted with a variety of aquatic ecosystems, which are of great scientific interest and economic importance. The reservoirs provide various services to people, such as irrigation and drinking water, flood protection, fisheries and tourism (Zwahlen R et al, 2003). Most of the Ethiopian reservoirs and lakes are very productive, inhabited by indigenous and exotic populations of edible fish and supporting a variety of aquatic and terrestrial wildlife. The physical regimes and the levels of lakes are governed by many natural and anthropogenic factors (Sene KJ and Yin X, 200). Fresh water bodies constitute a vital component of a wide variety of living environments as integral water resource base in many human societies in the world. They have been regarded as key strategic resources essential for sustaining human livelihood, promoting economic development and maintaining the environment (UNWDR, 2005). Utilization of freshwater resources include use as source of drinking water, fishing activities, sites for domestic and industrial effluents discharge, recreation and transportation activities.

Invasive species are widely accepted as one of the leading causes of biodiversity loss and can have significant effects on resource availability and can suppress the relative abundance of native species (Bhattacharya, A., et al., 2015; Patel, S., 2012). In Ethiopia, close to 35 invasive alien plant species are posing negative impacts on native biodiversity, agricultural lands, range lands, national parks, water ways, lakes, rivers, power dams, road sides, urban green spaces with great economy and social consequences (Rezene & Taye, n.d.). They may also alter biological communities and ecosystem structure and processes in terms of food web structure and energy flow

(Wondie, Z., 2013). At present Water hyacinth (*Eichhornia crassipes*) have been ranked as one of the world's worst invasive weeds (Villamagna & Murphy, 2016; Bhattacharya, A., et al., 2015) causing problems to millions of users of water resources. It is known as "Blue Devil" or "Bengal terror" in India, "Florida devil" in South Africa, "German weed" in Bangladesh and "Water terror" by South Western Nigeria with its disruptive impacts on aquatic ecosystem, agriculture, fisheries, transportation, living conditions and social structures (Bhattacharya, A., et al., 2015). Water hyacinth is justifiably called the world's worst aquatic weed due to its ability to rapidly cover whole waterways. In the absence of natural enemies, the weed quickly becomes invasive, colonizing slow moving waters resulting in thick and extensive mats (Edwards and Musil, 1975) which degrade aquatic ecosystems and limit their utilization (Hill and Coetzee, 2008). The negative impacts of water hyacinth are due to its dense, impenetrable mats which restrict access to water. These mats affect fisheries and related commercial activities, functioning of irrigation canals, navigation/transport, hydro-electric programmes and tourism (Navarro and Phiri, 2000). Ecologically, benthic and littoral diversity is reduced (Masifwa et al., 2001; Toft et al., 2003; Midgley et al., 2006), while population of vectors of human and animal diseases such as bilharzias and malaria are increased with water hyacinth infestation as these plants interfere with pesticide application (Harley et al., 1996).

Water hyacinth is a free-floating perennial (hydrophytes) plant native to tropical and sub-tropical South America. It has broad, thick, glossy, ovate leaves; it may rise above the surface of the water as much as 1 meter in height and have 80 cm root below the surface of water. The leaves are 10-20 cm across, and float above the water surface. They have long, spongy and bulbous stalks.

One of the fastest growing plants known, water hyacinth reproduces primarily by way of runners or stolons. Each plant additionally can produce thousands of seeds each year and seeds can remain viable for more than 28 years. (Julien MH (2012)). Some water hyacinths were found to grow up to 2 to 5 metres a day in some sites in Southeast Asia. It also doubles their population in two weeks. International Union for Conservation of Nature (IUCN's) lists this species as one of the 100 most dangerous invasive species and the top 10 worst weeds in the world.

The water hyacinth appeared in Ethiopia in 1965 at the Koka Reservoir and in the Awash River. Other infestations in the country include Gambela Region, the Blue Nile from just below Lake Tana into Sudan, and Lake Ellen near Alem Tena. This article, therefore, focuses on the reveal of the effect of water hyacinth on fishery resources and its expansion trends.

1.1. Objective

The purpose of this article is a detailed review of the effect of water hyacinth on fishery resources and its expansion trends in Ethiopia. The specific objectives are, therefore:

- To identify effect of water hyacinth on fishery resources
- To reveal water hyacinth expansion trends in Ethiopia
- To reveal the controlling techniques of water hyacinth expansion in Ethiopia.

2. Main Water Bodies of Ethiopia and Their Fisheries

For the sake of convenience, the country's water bodies are classified into four systems: lakes; reservoirs; rivers; and small water bodies. The lakes and rivers support highly diverse aquatic life, ranging from giant mammals like the African Hippopotamus, to microscopic fauna and flora. The natural ichthyofauna is also diverse, with more than 100 fish species, of which about 40 are endemic to the country. Including exotic species, about ten different species have been used for stocking artificial water bodies.

Table 1. Summary of Ethiopian water bodies and their fisheries

Water body type	Extent	Fishery potential (tonne/year)	Catch(tonne; 2001)	Off take
Major lakes	6 477 km ²	23 342	10 598	45%
Major reservoirs and dams	857 km ²	4 399	1 366	31%
Small water bodies	275 km ²	1 952	303	16%
Rivers	7 185 km	21 788	3 121	14%
Total		51 481	15 389	30%

Table 2. Major lakes

Water body	Altitude (m)	Shoreline (km)	Mean depth (m)	Area (km ²)	Fishery potential (tonne/yr)	Catch (2001; tonne)	Offtake
Tana	1829	385	8	3 500	10 000	1 454	15%
Ardibo and Lugo	670	–	37	51	400	330	83%
Ziway	1848	102	2.5	434	2 941	2 454	83%
Langano	1585	78	12	225	240	151	63%
Abijata	1578	–	7.6	205	2 000	500	25%
Shalla	1558	–	87	250	1 300	10	1%
Awassa	1708	52	11	97	611	853	140%
Abaya	1285	225	7	1 070	600	412	69%
Chamo	1282	118	6	551	4 500	4 359	97%
Turkana (from 1.3% of total area)	365	–	33	94	750	75	10%
Subtotal				6 477	23 342	10 598	45%

Table 3. Major reservoirs and dams

Reservoir or dam	Area(km ²)	Fishery potential(tonne/year)	Catch(2001; tonne)	Offtake
Koka	255	1 194	625	52%
Fincha-Amerti	250	1 330	333	25%
Beseka	39	205	41	20%
Denbi	72	383	77	20%
Melka Wakena	82	434	109	25%
Aba-samuel	44	234	59	25%
Alwero dam	74	394	79	20%
Hashengie	20	106	21	20%
Small Abya	12	66	13	20%
Wedecha	10	53	11	20%
Subtotal	857	4 399	1 366	31%

Table 4. Small water bodies

Waterbody	Area ⁽¹⁾	Fishery potential(tonne/year)	Catch (2001; tonne)	Offtake
Southern region (ChelelokaSwamp)	100	423 ⁽²⁾	21	5%
Gambella (swamps and flood plains)	125	529 ⁽²⁾	132	25%
Small reservoirs and ponds	50	1 000 ⁽³⁾	150	15%
Subtotal	275	1 952	303	16%

Notes: (1) Area for SWBs are rough estimates. (2) Swamp potential catch is calculated from $A \times 4.23$, where A is the area in km², and 4.23 is the average yield in t/km². (3) Potential catch based on an average yield of 200 kg/ha (= 0.2 tonne/km²) Sources: FAO, 1994. Small water bodies and rivers in southern Africa, edited by B. Marchal & M. Maes.

Table 5. Major Rivers

River	Total length (km)	River length within Ethiopia(km)	Fishery potential((tonne/year)	Catch(2001; tonne)	Offtake
Abay	1 450	800	2 133	213	10%
Wabi Shebele	1 130	1 000	3 333	333	10%
Genale	858	480	768	77	10%
Awash	1 200	1 200	4 800	480	10%
Omo	760	760	1 925	481	25%
Tekeze	608	608	1 232	123	10%
Mereb	440	440	645	65	10%
Baro	277	277	256	26	10%
Angereb	220	220	161	16	10%
Subtotal	6 943	5 785	15 255	1 814	12%
Miscellaneous small rivers		1 400	6 533	1 307	20%
Total rivers		7 185	21 788	3 121	14%

Notes: (1) Area for SWBs are rough estimates. (2) Swamp potential catch is calculated from $A \cdot 4.23$, where A is the area in km², and 4.23 is the average yield in t/km². (3) Potential catch based on an average yield of 200 kg/ha (= 0.2 tonne/km²) Sources: FAO, 1994. Small waterbodies and rivers in southern Africa, edited by B. Marchal & M. Maes.

3. Overview of Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) is a free floating perennial (or hydrophyte) aquatic weed and one of the major challenging problems in water bodies of the tropics and sub-tropics which originated from the Amazon Basin and has dispersed very rapidly in many countries of Latin America, Africa, Southeast Asia and Pacific in 1950 (Patel). Water hyacinth was introduced in different parts of the world as a beautiful garden plant (ITDG, 1999; Labrada et al., 1996; Shanab et al., 2010). It is characterized by rapid growth rate and infestation on large water area causing different problems (Shanab et al., 2010; Zhang et al., 2010). The weed affects solar light penetration into water bodies, reduces oxygen through decomposition, alters chemistry of water and substantially increases water evapotranspiration (ITDG, 1999).

Water hyacinth has spread in more than 50 countries worldwide and has become a problem especially in the tropics and sub-tropical countries like Latin America and the Caribbean, Southern United States of America, Southern Africa, West Africa, South-East Asia and the Pacific (ITDG, 1999; Labrada et al., 1996). In Africa, the water hyacinth has been a problem since the 1990's. It has infested the Nile River of Egypt, Tano Lagoon water areas of Ghana; Comoe River of Ivory Coast; Lake Victoria shared by Kenya, Uganda and Tanzania; Congo River in DRC; and Lake Kariba and Kafubu River of Zambia (Labrada et al., 1996; ITDG, 1999; SANTREN, 2006).

The water hyacinth appeared in Ethiopia in 1965 at the Koka Reservoir and in the Awash River. Other infestations in the country include Gambela Region, the Blue Nile from just below Lake Tana into Sudan, and Lake Ellen near Alem Tena.

3.1. Factors Promoting the Growth and Infestation of Water Hyacinth

The world has experienced rapid population growth, industrialization, urbanization and land use change for the past years. These anthropogenic activities have often lead to increase in the waste generated and crop production to cater for the growing population (Harley et al., 1997). Industrial and domestic wastewater carry along nutrients and eventually find their way into water bodies as run-off (Harley et al., 1997). The unpredictable rapid growth rate of the weed is attributed by the eutrophication and absence of natural enemies of the plant in water bodies which cause the weed to bloom (Labrada et al., 1996). Cilliers (2003) observed that the South African River Vaal has experienced an increase in nutrients levels due to run-off which carry along fertilizer from agricultural practices, industrial and mining effluents, and wastewater from settlements. This in turn has caused rapid growth of water hyacinth in the River. Water hyacinth has grown rapidly in Lake Victoria due to run-off and wastewater carrying nutrients from agricultural activities and settlements which find its way into Lake (Williams et al., 2007). Wilson et al. (2007) considered temperature as one of the strongest determinants for the growth and reproduction of water hyacinth. The increase in temperature leads to rapid growth and reproduction of water hyacinth. These physical and chemical parameters will help identify the pollution sources that cause the infestation of water hyacinth in the River.

3.2. Economic Benefit of water hyacinth

Water hyacinth has limited beneficial uses. It cannot be used as a livestock feed because it contains too much silica,

calcium oxalate, potassium and too little protein. It cannot be directly used as a fertilizer because its C: N ratio is too high necessitating addition of N-fertilizer (Makhanu 1997).

Its economic significance stems from its potential to produce negative consequences for the habitat quality of water bodies. The 'mats' of aquatic plants reduce dissolved oxygen by restricting the exchange of oxygen across the air/water interface. They also affect wind-driven water movement and impede mixing of oxygen-rich surface water (Smith-Rogers 1999). It also generates large amounts of organic matter. As the organic matter decomposes, biological oxygen demand increases and water quality deteriorates. The oxygen can be reduced to such low levels that it leads to massive fish kills due to oxygen depletion in the water column (Muli, 1996).

In shallow lakes and where plant production is great, complete deoxygenation of the sediments and deeper water can occur. Such conditions are not compatible for the survival of fishes and invertebrates. Moreover, under anoxic conditions, ammonia, iron, manganese and hydrogen sulphide concentrations can rise to levels deleterious to biota. In addition, phosphate and ammonium are released into the water from anoxic sediments, further enriching the ecosystem (International Development Research Centre 2000).

4. Effects of water hyacinth on Fishery Resources

4.1. Effects of water hyacinth expansion on fishing

According to Cho & Tifuh, (2012) when water hyacinth infestation is present, access to fishing sites become difficult for riparian communities which rely solely on fishing as their main economic activity. Similarly, a study by Frezina, (2013) also reported that water hyacinth can present many problems for the fisherman. Water hyacinth provides highly complex habitat structure by restricting the growth of other submersed macrophytes. This modification and habitat complexity at the surface of the water are likely affect fishing. In the area of severe infestation, especially around the shore area fishing is therefore too much difficult. This results in blockage of fish landing sites and destruction of fishing gear (Opande, G.O., et al., 2004). Hence, as much as water hyacinth is viewed; it has had a negative impact on fishing, as it causes difficulty in fishing (Mitchel, 2014). Water hyacinth can also greatly affect fish catch rates, because mats of water hyacinth can block access to fishing grounds and clog eye of the net. Therefore, for fishermen, the hyacinth mats have reduced their catch by covering the grounds, increasing fishing costs because of the time and effort spent in clearing waterways, and causing loss of nets. It had inflicted heavy financial burden on the surrounding fisher folk, who complained that their fishing ground was infested with the weed, fish landings had dwindled and that even navigation had become impossible in the infested areas. Similarly, Aloo, P., et al., (2013) reported that many landing sites have been abandoned and income generation from the sale of fish has been negatively affected. A study by Kateregga & Sterner, (2009) confirmed that fish stocks decline have been at least temporarily halted by the declining catch ability of fish because of the growing abundance of water hyacinth. A study in Lake Victoria by Bhattacharya, A., et al., (2015) also showed fish catch rates decreased by 45% because water hyacinth mats blocked access to fishing grounds, delayed access to markets and increased costs (effort and materials) of fishing. Similarly, Mailu, (2001) and Mitchel, (2014) stated that the hyacinth mats reduced their catch by covering fishing grounds, delaying access to markets due to loss of output, increasing fishing costs due to the time and effort spent clearing waterways, forcing translocation, and causing loss of nets.

The ability of the aquatic weed to reproduce rapidly affects socio-economic activities such as hampering fishing as the weed makes it difficult to access open areas, entangles boat propellers and clogs waterways (Ndimele et al., 2011; Patel, 2012). Water hyacinth makes it difficult to transport goods and reduces fish catch on water bodies, and more fuel is consumed when water hyacinth infestation is high (Labrada et al., 1996). Water hyacinth reduces fish stock for Tilapia and young Nile Perch by limiting access to breeding, nursing, and feeding grounds (Twongo and Howard, 1998; Villamagna and Murphy, 2010). Fishermen also find it difficult in carrying out fishing activities due to the presence of water hyacinth infestation (ITDG, 1999).

According to Patel (2012) water hyacinth entangles with boat propellers, and makes it difficult for fishermen to move as it is an impenetrable barrier to canoes. Water hyacinth in water bodies create a difficult scenario for fishermen to access fishing sites, which leads to loss of fishing equipment as a results of nets entangling into the root systems of the weed (ITDG, 1999). Labrada et al. (1996) observed that fewer fish, by number and weight, are found in water hyacinth areas with smaller fish diversity. For example (Tilapia spp.) are commonly found in open area, but find it difficult to adopt in weed infested areas. Dissolved oxygen which is less than 5 mg/ l adversely affect function and survival of most fish, while below 2 mg /l can lead to fish death (Chapman, 1996).

4.2. Impacts of water hyacinth on Fish Catchability

Impacts of the water hyacinth on fish communities depend on the initial community composition and structure, the existing food web, and water hyacinth density or area cover (Grenouillet et al., 2002; Lewin et al., 2004). The structure of water hyacinth on the water surface restrict vegetation growth beneath the water, which affects and reduces fish as the surface of water is modified and fish cannot adapt to a new environment (Meerhoff et al., 2006; Meerhoff et al., 2007). Water hyacinth affects fish catchability especially when dissolved oxygen is reduced as a

result of dense water hyacinth mats, this risk killing the fish (Kateregga and Sterner, 2009).

4.3. Effect of Water Hyacinth on Fishing Equipment

Access to sites becomes difficult when weed infestation is present, loss of fishing equipment often results when nets or lines become tangled in the root systems of the weed. Therefore, fishers turn back to the landing site after they lost a lot of extra fuel and labor without any or with a minimum catches. Furthermore, each branch of water hyacinth becomes attached to the fishing net, and when the fishers pull their fishing net (mostly monofilament gillnet) during fishing it becomes damaged. Besides repairing the damaged fishing net, fishers invest considerable amount of time on detaching water hyacinth parts (branches) from gillnet after catching or fishing. According to an interview with a key informant by Mitchel, (2014) also revealed 'fishers experience loss of fishing gear, time wasting during fishing and difficulty in movement, and even sometimes prevent people from fishing'. All these lead to reduction in fish catch and subsequent loss of livelihood. On the other hand, an area of sparsely infested water hyacinth dawdles the speed of the fishing boat by raveling the propeller. This reduces the energy of the motorized boat without reducing the amount of fuel consumed. This leads to increase in their expenditure on fuel for their boat's engine. However, in a densely infested area fishing by using both types of boats (motorized and reed boat) is unimaginable.



Figure 1. Entanglement of fishing boat

According to the focus group discussion and key informant interview, artisanal fishers, who couldn't enter into the pelagic area using reed boat, are highly vulnerable to the problems derived by water hyacinth. Therefore, water hyacinth affects smallholder fishers by increasing costs of fishing and reducing the amount of catch per unit of effort (CPUE).



Figure 2: Shore area infested by water hyacinth.

Furthermore, some fishers fishing in the areas that are highly infested by water hyacinth (figure 1) are risky because of the weed slow down the speed of the boat and they couldn't escape from a hippopotamus. Even though originally perceived as a practical problem for fishing and navigation, recent research indicates that aquatic weeds are now also considered a threat to biological diversity affecting fish fauna, plant diversity and other freshwater life and food chains (Aloo, P., et al., 2013). Moreover, Gichuki et al., (2012) reported that the weed forms thick mats over the infested water bodies causing obstruction to economic development activities and impacting negatively on the indigenous aquatic biodiversity. Eventually, further expansion of this plant will lead to drying up and shrinking of the lake. Depending on the degree of evapo-transpiration and the lake size, there would be completely dry-up and disappearance of the Lakes. Aba Samuel reservoir is a small lake near Addis Ababa was choked with water hyacinth and completely dried up in recent memory (Seyoum, 2013).

5. Expansion Trends Water Hyacinth in Ethiopia

5.1. Water Hyacinth Expansion in Lake Tana

In 2012, water hyacinth had proliferated and covered about 15% of the Northern shore of the Lake. Due to this infestation, a massive annual removal campaign was organized by the regional government in 2013 and more than 40,000 farmers were involved (Seyoum, 2013). Even though such a massive physical removal was implemented, water hyacinth flourishes alarmingly year to year. According to a 2014 assessment study of Wassie et al. (2014) close to one-third or more than. Furthermore, the reports of Bahir Dar fisheries and other aquatic life research center (annual report) (2015) and Wassie et al. (2015) showed the current (2015) estimate of water hyacinth infestation coverage is approximately 34,500 ha (3,000 ha thick, 2,500 ha intermediate and 29,000 ha scattered). However, thick mat covered areas are smaller in the 2015 survey than in 2014, this is largely as a result of the community based mass physical removal campaign and to some extent long dry season dormancy

5.2. Prevalence and Intensity of Water Hyacinth Infestation in water body of Rift valley

Field assessment on the prevalence and intensity of water hyacinth infestation indicated that the weed was prevalent in all the surveyed water bodies with different magnitude of infestation. About 75% of the surveyed water bodies had more than 50% infestation level. Moreover, variations in the prevalence and level of infestation of water hyacinth were observed among and within the surveyed water bodies (Table 6). Fifty percent of the water bodies had more than 87% infestation (Table 6). The highest water hyacinth prevalence was recorded in Ellen (100%), Melka Hida (100%), Dodo wedera (98%) and Tere(96%), while the lowest (<20%) was recorded at Wonji-Shoa. In addition, the highest water hyacinth count [308 plants per quadrat (m^2)] was recorded at Koka Dam, whereas the lowest [12.00 plants per quadrat (m^2)] was found in Wonji-Shoa. This result agreed with a previous diagnostic survey result, whereby under severe infestation the number of water hyacinth reached up to 348 plants per quadrat (Dula et al., 2008). This shows the importance of water hyacinth in the surveyed water bodies.

On the other hand, the interviewed people around Koka and Abasamuel Dam reported that there was severe infestation of the water bodies with water hyacinth prior to the survey period. Similarly, Senayit et al., (2004) reported that the water bodies showed different level of water hyacinth infestation depending on the climatic factors. In most of the surveyed water bodies, it was found that high mats of water hyacinth infestation was prevalent in the border and shaded areas. This could be due to the high wind current blown over the water bodies and decrease in the water depth. In line with this, reports indicated that population dynamics of water hyacinth can be affected by the water level fluctuation and wave action (Wilson et al., 2001). However, water hyacinths can still build-up on sheltered edges and at blockages.

Among the water bodies surveyed Lake Ellen, Melka Hida, Golodee, Dodo Wedera and Tere were having a dense and serious infestation with mean infestation of 4-5 abundance scale, while Koka Dam, Awash River, Sire Robi and Bate-gurame have medium infestation

(Table 6). The lowest infestation was recorded at Lake Abasamuel, Wonji Shoa and Afer Gidib.

Similarly, previous survey result showed that the infestation of water hyacinth on critical water bodies of Wonji-Showa Sugar Estate was reduced by over 73% within a period of 2 years, and only localized water hyacinth infestations were obtained with a magnitude ranging from free to low level in most parts of water bodies as a result of integrated management strategies performed by the Estate (Dula et al., 2008).

Table 6: Prevalence, extent of infestation and infestation level of water hyacinth in the surveyed 12 water bodies of the Rift Valley

Water bodies	Numbers of spots of waterbodies observed	Approximate distance of distance from the border (m)	*Water hyacinth Prevalence (%)	Abundance scale	Infestation level	Mean water hyacinth count	^b Number of water bodies with in water hyacinth density count count interval	
							<250/m ²	251-350/m ²
Abasamuel	44	5.65	45	No inf _n to 5	Fto H	64.27	14	1
Afer Gidib	10	5.72	40	No inf _n to 4	F to M	261.00	2	2
Awash River	18	25.07	89	No inf _n to 5	F to H	185.63	7	9
Bate Gurmame	12	8.03	58	No inf _n to 4	Fto M	278.00	4	3
Dodo Wedera	44	77.50	98	5 to 6	H	243.81	24	19
Ellen	33	157.06	100	5 to 6	H	276.12	13	20
Ellen Golode	15	55.92	87	5 to 6	H	257.54	6	7
Koka Dam	10	9.67	60	3 to 6	M to H	308.00	1	5
Melka Hida	15	27.54	100	5 to 6	H	250.8	9	6
Sire Robii	32	12.40	88	3 to 6	M to H	283.00	11	17
Tere	24	40.78	96	5 to 6	H	211.04	9	14
Wonji-Shoa	17	2.00	18	No inf _n to 1	F-L	12.00	3	0
Mean	22.83	35.61	73.21			219.27	8.58	8.58

NB- F- Free, M- Medium, H- High, L- low and No in inf_n- No infestation

^aThe percent of water bodies where water hyacinth prevailed, ^b Water hyacinth population count per quadrat with in the range

6. Control Measures for water hyacinth

The main control methods for management of water hyacinth are:

I. Biological control:- Biological control is most effective on large area of water hyacinth but it may take many years to achieve Satisfactory control. Currently due to financial and environmental degradation associated with chemical control actions and their negative factors has increase led to use of biological control measures Researches into implement of biological control approach was initiated in 57 years ago by United state Department of Agriculture and to date seven arthropods, that disturb water hyacinth in its origin have been released for bio control in many countries (Tipping et al., 2014). Presently, findings reported that application of biological natural enemies for the control of water hyacinth is the most effective, economical and sustainable control methods as the control persists for long time with little ongoing cost and without environmental impact (Firehun et.al 2013). In Ethiopia, although the control of water hyacinth by using biological control agent still is not beyond experimental stage, the use of bio control agent at the national level has received attention and researchers have become engaged in surveys and evaluate classical and native bio control agents (Firehun et.al 2015). According to Firehun et.al (2013) reported that the application of fungal pathogen for the control of water hyacinth showed 11-67, 22-72, 15-55 and 12-50% reduction in fresh weight, dry weight, plant height and root length of water hyacinth, respectively.

II. Physical control:- Water hyacinth removal by hand machine is a practical control method often used for small areas or when numbers are low. Physical removal is most effective for small infestation and should be made before flowering and seed set. Mechanical control of water hyacinth can help take advantage of flooding or water flush that deposit water hyacinth in dams and calm water areas of rivers. When using this approach, it is essential water hyacinth is removed before its rapid growth commences. Mechanical control operation are commons in Ethiopian lakes and rivers. However, regrowth of the chopped weed is likely to take place, especially if the natural enemies are not well protected during chopping. In addition, shallow area of the lake and river are likely to fill up with vegetation especially along the shoreline, leading to subsequent reduction in size of lake and river (Yigrem and Yohannis 2019)



Figure 3. Manual pulling of water hyacinth at shore line

III. Chemical control: - Chemical control is other option. Public opinion all over the world is against the use of herbicides in water biodiversity, but the use of herbicides seems to be unavoidable in certain circumstance and, if they are applied properly and with caution environmental problem can be avoided. In addition to environmental concern, another constraint is the need to purchase simple spraying equipment to be mounted in a boat to apply the herbicide on water bodies (Firehun et al., 2013). Among the herbicides glyphosate is safest for use in water body, however, cost of application (no less than US\$28/ha) would be prohibited in some countries (Dagno et al., 2012). Another option is 2-4-D, seems to be safe for fish, and is rapidly degraded in the environment and much cheaper than glyphosate. Application of any of these herbicides should be made in specific infested sites, but never in overall application to the whole infested area to avoid the depletion of water oxygen availability due to incorporation into the water of the destroyed water hyacinth mass. Firehun et al (2009) reported that it is most excellent for little invasion area not big areas. Apart from the three control methods, Afework (2008) recommended to if the amount of nutrients incoming any water body is decrease, this repetitively reduce the invasion and expansion of the water hyacinth.

IV. Integrated control approach:- Integrated control of water hyacinth is a sensible approach that includes the combination of mechanical, biological and chemical methods that complement each other. Because of rapid dispersal habit of water hyacinth and among practical constraint and financial cost associated with physical, mechanical, biological and chemical control measures alone are not effective for the control of water hyacinth. Thus, integrated managements that stress the weeds over a longer period of time are usually required for effective control particularly for established infestation. To sustainably manage the abundance of water hyacinth weed; an advance integrated weed management approach is very essential, where manual, mechanical, biological and herbicides are being jointly implemented (Afework et al., 2008)

CONCLUSION AND RECOMMENDATION

Water hyacinth abundance in worldwide has been manifested on large scale in many water ecosystems including Ethiopia. Like climate change and other anthropogenic activities, the newly emerged water hyacinth becomes a big threat for water bodies in general and the fishers in particular. If the expansion of this aquatic invasive weed continues at this rate, the livelihood of subsistence fishers could be endangered because of water hyacinth strongly reduces the efficiency of fishing. Based on the review the use of bio control agent is the most effective, economical and sustainable management approach for water hyacinth. In Ethiopia management of this invasive weed is still under a trial stage. However, the use of biological control agent to reduce the level of water hyacinth at the national level has received a big attention and researchers have become engaged in conducting research. Therefore, the government and other concerned stakeholders must surmount their facilitation and coordination role in reducing the disastrous effect of the weed on the society was mandatory.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgments

The authors are thankful to library and ICT office of Haramaya University and Yabello Pastoral and Dryland Agriculture Research Center for providing the facilities to prepare this review paper.

7. REFERENCES

- Afework D. (2008). Efficacy of integrated water hyacinth (*Eichhornia crassipes* [mart] solms) management strategies at wonji-shoa sugar factory. Ambo university college, Ethiopia.
- Aloo, P., Ojwang, W., Omondi, R., Njiru, J. M., & Oyugi, D. (2013). A review of the impacts of invasive aquatic weeds on the bio- diversity of some tropical water bodies with special reference to Lake Victoria (Kenya). *Biodiversity Journal*, 4(4), 471–482.
- Asmare, E., Tewabe, D., Mohamed, B., & Hailu, B. (2015). Pre-Scaling Up of Solar Tent Fish Drier in Northern and North Western Part of Lake Tana , Ethiopia. *International Journal of Aquaculture and Fishery Sciences*, 1(2), 48–53.
- Asmare, E., Demissie, S., & Tewabe, D. (2016). Fisheries of Jemma and Wonchit Rivers : As a Means of Livelihood Diversification and its Challenges in North Shewa ZonEthiopia,7(7).<http://doi.org/10.4172/21503508.1000182><http://doi.org/10.17352/2455-8400.000009>.
- Ayenew T. (2002). Recent changes in the level of Lake Abiyata, central main Ethiopian Rift. *Hydrol. Sci. J.*; 47(3): 493–503.
- Bhattacharya, A., Haldar, S., & Chatterjee, P. K. (2015). Geographical distribution and physiology of water hyacinth (*Eichhornia crassipes*) – the invasive hydrophyte and a biomass for producing xylitol. *International Journal of ChemTech Research*, 7(4),1849–1861.
- Brehan, M., Martin, de G., Leo, N., Wassie, A., & Minwelet, M. (2011). Lake Tana's (Ethiopia) endemic

- Labeobarbus spp. Flock: An uncertain future threatened by exploitation, land use and water resources developments. In L. Brook & G. Abebe (Eds.), Impacts of climate change and population on tropical aquatic resources, proceedings of the Third International Conference of the Ethiopian Fisheries and Aquatic Sciences Association (EFASA) (pp. 285–297). Addis Ababa: AAU Printing Press.
- Dagno K, Lahlali R, Diourte M, Jijakli H: Fungi occurring on waterhyacinth (*Eichhornia crassipes* (Martius) Solms-Laubach) in Niger River in Mali and their evaluation as mycoherbicides. *Journal of Aquatic Plant Management* 2012, 50:25-32.
- Daniel, W., Feleke, Z., & Seyoum, L. (2011). Potential of water hyacinth (*Eichhornia crassipes* (Mart.) Solms) for the removal of chromium from tannery effluent in constructed pond system. *SINET: Ethiop. J. Sci.*, 34(1), 49–62.
- Dereje, T. (2015). Preliminary Survey of Water Hyacinth in Lake Tana, Ethiopia. *Global Journal of Allergy*, 1, 13–18. <http://doi.org/10.17352/2455-8141.000003>
- Dula, A., Taye, T. and Y. Firehun. (2008). Efficacy of Integrated Water Hyacinth (*Eichhornia crassipes* [Mart] Solms-Laubach.) Management Strategies at Wonji-Shoa.
- Firehun Y, Yohannes Z: Evaluation of some herbicides against water hyacinth (*Eichhornia crassipes* [Mart.] Solms) at Wonji-Shoa. In Proceedings of Ethiopian Sugar Industry Biennial Conference. 2009: 61-68.
- Firehun Y, Struik P, Lantinga E, Taye T: Joint use of insects and fungal pathogens in the management of water hyacinth (*Eichhornia crassipes*): Perspectives for Ethiopia. *J Aquat Plant Manage* 2013, 51.
- Firehun Y, Struik P, Lantinga E, Taye T: Adaptability of two weevils (*Neochetina bruchi* and *Neochetina eichhorniae*) with potential to control water hyacinth in the Rift Valley of Ethiopia. *Crop Protection* 2015, 76:75-82
- Said R. (1993). *The River Nile, Geology, Hydrology and Utilisation*, Pergamon Press, UK.
- Julien MH (2012). *Eichhornia crassipes* (Martius) Solms-Laubach – water hyacinth. In: Biological control of weeds in Australia. Julien M (editors), et al. pp. 227-37. (CSIRO Publishing, Melbourne)
- Patel S: (2012). Threats, management and envisaged utilizations of aquatic weed *Eichhornia crassipes*: an overview. *Reviews in Environmental Science and Bio/Technology* 11:249-259.
- Seleshi B .(2007). Water challenges, innovations and interventions for Ethiopia, Think Tank paper on water resource (Unpubl).
- Senayit, R., T. Agajie, T. Taye, W. Adefires, and E. Getu. 2004. Invasive Alien Plant Control and Prevention in Ethiopia. Pilot Surveys and Control Baseline Conditions. Report submitted to EARO, Ethiopia and CAB under the PDF B phase of the UNEP GEF Project Removing Barriers to Invasive Plant.
- Sene KJ. Theoretical estimates for the influence of Lake Victoria on flows in the upper White Nile. *Hydrol. Sci. J.*, (2000); 45(1):125-146.
- Seyoum M (2013) Will water hyacinth become established in Lake Ziway? In: Brook L, Seyoum M, Elias D, Zenebe T, and Tadesse F (eds.) Trends in the conservation and utilization of the resources of the Ethiopian Rift valley Lakes, paper presented at the 5th annual conference of the Ethiopian Fisheries and Aquatic Sciences Association (EFASA), Hawassa pp: 50-78.
- Tipping PW, Sosa A, Pokorny EN, Foley J, Schmitz DC, Lane JS, Rodgers L, Mccloud L, Livingston-Way P, Cole MS: Release and establishment of *Megamelus scutellaris* (Hemiptera: Delphacidae) on waterhyacinth in Florida. *Florida Entomologist* 2014, 97:804-806.
- Wassie A, Minwuyet M, Ayalew W, Dereje T, Woldegebrael W, et al. (2014) Water hyacinth coverage survey report on Lake Tana. Technical Report Series 1.
- Wassie A, Dereje T, Addisalem A, Abebaw Z, %ciaT, et al. (2015) Water hyacinth coverage survey report on Lake Tana biosphere reserve Technical survey report series 2.
- Wilson, J.R., M. Rees, N. Holst, M.B. Thomas, and G. Hill. 2001. Water hyacinth population dynamics. 102, 152 p. In: Julien, M.H., Hill, M.P., Center, T.D. and Ding Jianqing, ed. (2001). Biological and Integrated Control of Water Hyacinth, *Eichhornia crassipes*. Proceedings of the Second Meeting of the Global Working Group for the Biological and Integrated Control of Water Hyacinth, Beijing, China, 9–12 October 2000.
- Yigrem Mengist and Yohannes Moges (2019). Distribution, Impacts and Management Option for Water Hyacinth (*Eichhornia Crassipes* [Mart.] Solms) in Ethiopia: A Review. *Journal of Advances in Agriculture*. 10:23490837. DOI: <https://doi.org/10.24297/jaa.v10i0.8308>
- Yin X. Nicholson SE. and Ba MB. On the diurnal cycle of cloudiness over Lake Victoria and its influence on evaporation from the Lake. *Hydrol. Sci. J.* 2000; 45(3): 407-424.
- Zwahlen R. (2003). 'Identification, Assessment, and Mitigation of Environmental Impacts of Dam Projects.' In R.S. Ambast and N.K. Ambast (eds), *Modern Trends in Applied Aquatic Ecology*. Kluwer Academic/Plenum Publishers, New York. 281-368.