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Review

Water quality problems, related challenges and their impacts on Ethiopian fishery

Agumassie Tesfahun

Department of Biology, College of Natural and Computational Sciences, Ambo University, P. O. Box 19, Ambo, Ethiopia.

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The purpose of this review article is to explore the drivers of the water quality problems and associated impacts and mitigation schemes of the fishes and fisheries in Ethiopia. Data were obtained from both published and unpublished online documents as well as from different Ethiopian universities and institutions. The country has the potential to produce more fish yield (94, 500 ton/year. The published and unpublished documents stated that the fishes and water bodies utilized are under stress such as textile industry, floriculture industry, tannery industry, high population growth, irrigation, application of agrochemicals, deforestation around the watershed, types of fishing gears, fishing methods, socio-economic factors, lack of facilities and infrastructure, ineffective administration setup, invasive weeds, land use around the fish habitats. However, the demand for fish is increasing at an alarming rate time to time. For this reason, good management setup for stakeholders particularly those communities settled around the watershed awareness is critical to sustain fish and water resources for the upcoming generation in the country.

Key words: Ethiopia, fishery, management, watershed, water quality.

INTRODUCTION

Ethiopia is endowed with inland aquatic ecosystems including lentic and lotic water bodies namely the Rift Valley, Abay, Awash, Baro-Akobo, Omo-Gibe, Tekeze and Wabishebele-Genale drainage basins (Awoke, 2015; Utaile and Sulaiman, 2016). Ethiopian important commercial fishes were widely distributed in the aforementioned drainage basins (Golubtsov and Mina, 2003). Besides this, these drainage systems consist of diverse indigenous fishes; they are highly productive and contribute to the local and national economy (Reyntjens et al., 1998; Tudorancea and Taylor, 2002). In addition to fish production, the water bodies are the habitats of aquatic biota like plant (flora) and animal (fauna) biological communities. However, recently the aquatic lives including fishes are affected due to the alteration of water quality. Water pollution is a global problem and it needs urgent attention (Abrehet et al., 2015; Ali et al., 2008). Human induced activities that lead to aquatic pollution, number of industries, agricultural and commercial chemicals discharged into the water bodies cause various deleterious effects on the aquatic biota (Ali et al., 2008). Fishes can accumulate pollutants directly

E-mail: agumas2012@yahoo.com. Tel: +251916184242.

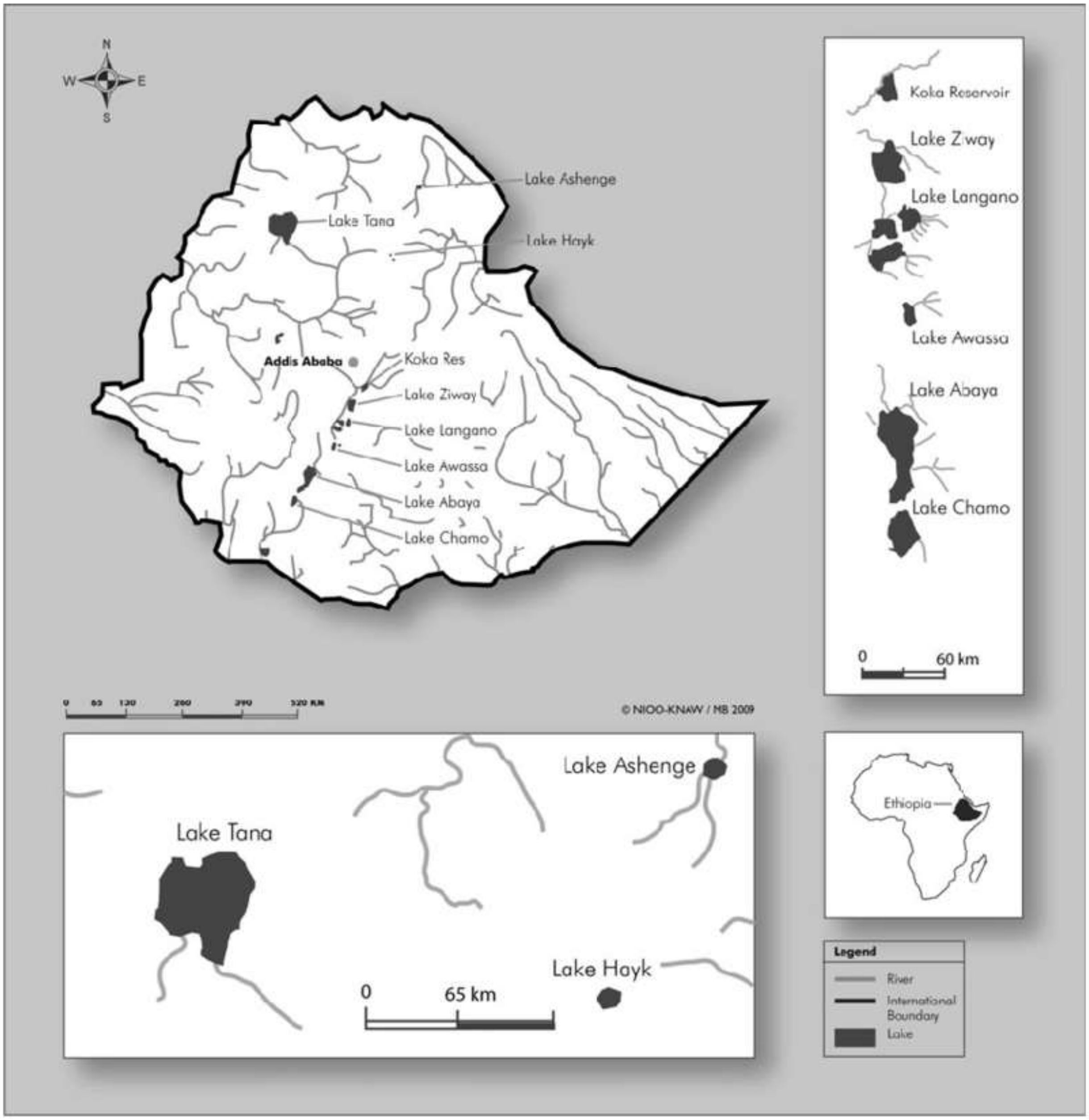

Figure 1. Some of the Ethiopian lakes.
Source: (Tesfaye and Wolff, 2014).

from the water sediment or indirectly from contaminated water and through the food chain (Dawodu et al., 2015; Desta et al., 2006). In other words, the water quality parameters such as salinity and turbidity reveal increasing trends due to anthropogenic activities within the catchments and having drastic effect on fish production (Utaile and Sulaiman, 2016). Various studies have been conducted on human activities and their impacts in Ethiopian water bodies (Yohannes et al., 2013; Worako, 2015; Berehanu et al., 2015) such as Lake Hawassa (Utaile and Sulaiman, 2016), Lake Chamo, (Desta et al., 2015; Desta et al., 2017), Lake Ziway (Goshu and Aynalem, 2017; Gebremedhin et al., 2018), Lake Tana, (Abrehet et al., 2015), Blue Nile River (Minuta and Jini, 2017), and Walleme River Southern Ethiopia (Figure 1). Good water quality plays an important role in wild fishes and aquaculture development in the country (Utaile and Sulaiman, 2016). There is little or no compiled information on the causes of water pollution and its impacts on Ethiopian fisheries. Therefore, this review paper aims to fill this gap and provide useful information for the proper management of water bodies and fishes for

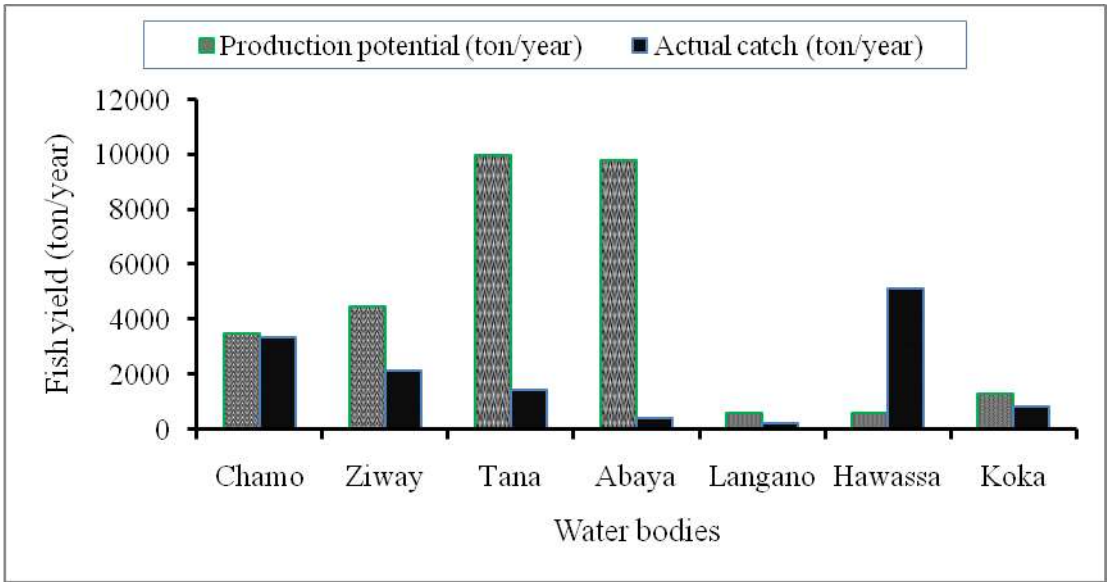

Figure 2. The production potential and the actual exploitation rate (ton/year) of fish in major Ethiopian lakes. Source. (Janko, 2014).

continued fishing in Ethiopian water bodies.

MATERIALS AND METHODS

A range of literature sources used for this review were collected from August 2018 to October 2018; they include journal articles (from the Internet data bases), workshop proceedings, FAO reports, bulletins, legal documents, (from University libraries and Ethiopian Ministry of Livestock and Fishery).

Production potential, catch and challenges of fishes in the water bodies of Ethiopia

Fishery in Ethiopia only depends on inland water systems (Janko, 2014). Accordingly, the country has the potential to produce 94,500 ton/year (FAO, 2012). However, the actual exploitation of fish production is 15,389 ton/year (Janko, 2014). In other words, only 31% is being utilized. For instance, Lake Abaya and Lake Tana have the potential to produce 9800 ton/year and 10,000 ton/year of fish yield respectively (Figure 2). However, the exact exploitation of the capture fishery is less when compared to the production potential of Ethiopian water bodies. This is might due to several reasons. Vijverberg et al. (2012) pointed out that habitat degradation and destruction are the main causes of fish stock depletion of freshwater fishes and this why fish population differs per water body, even from habitat to habitat. Sustaining species richness is one of the main issues of conservation in fisheries biology. So, that site specific management is vital in fishery biology and fish community conservation.

Major lakes contribute a total of 23,342 ton/year production potential and catch 10,598 ton/year. Major reservoirs and dams have production potential of 4399 ton/year and 1366 ton/year of catch. Rivers have the potential to produce catch of 21,788 ton/year and 3121 ton/year. Even, small water bodies have the potential to produce 1952 ton/year and 303 ton/year of the actual exploitation fish stock (Janko, 2014) (Figure 3). According to Goshu and Aynalem (2016), the drawbacks of unsustainable fisheries utilization in Lake Tana were the introduction of monofilament gillnet that has a mesh size less than the recommended one (less than 10 cm mesh size), habitat destruction, targeting spawning aggregation of migratory fishes at river mouths, pollution from the basin, sedimentation, hydrological regime change, invasive weeds, urbanization, and use of fish poisonous plants like *Millettia ferruginea*, which massively kills fishes of different type and age groups. Moreover, the challenges of Ethiopian fisheries and fishes are summarized as types of fishing gears, fishing methods, socio-economic factors, lack of facilities and infrastructure, ineffective administration setup, lack of expertise, land use around fish habitats, and lack of scientific data (Temesgen and Getahun, 2016).

Causes of water pollution, related challenges and the consequences on Ethiopian fisheries

Aquatic ecosystems are important for different communities such as irrigation, livestock watering, fisheries and recreational purposes. Moreover, greater than 183 fish species are found in Ethiopia. The production potential of the Ethiopian water bodies is

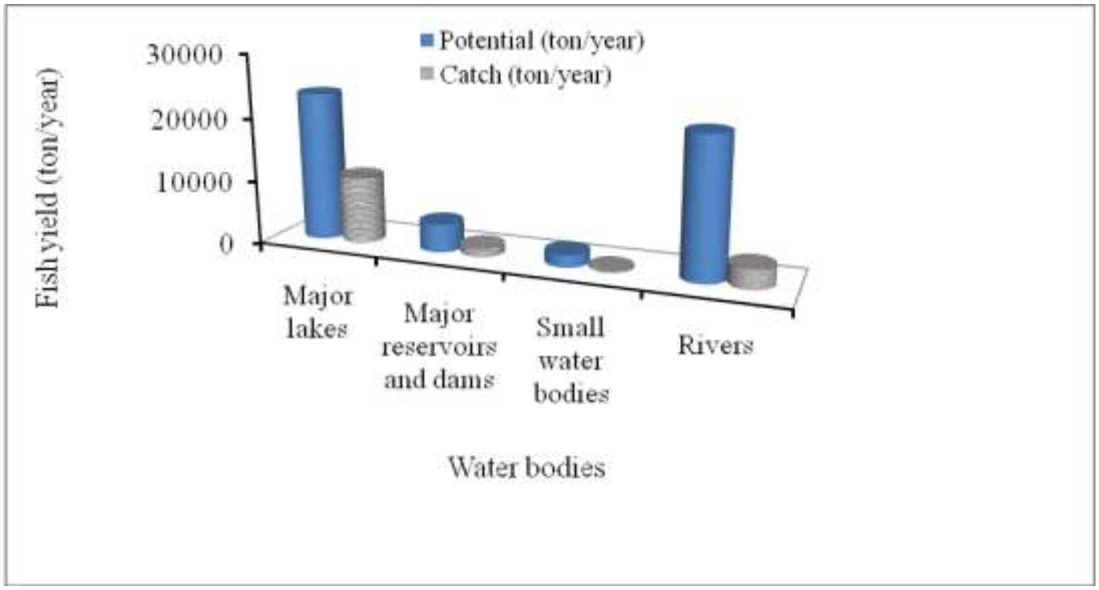

Figure 3. The production potential and the actual exploitation rate (ton/year) of fish in major and small Ethiopian water bodies.
Source: (FAO, 2012; Janko, 2014).

assumed to be 94,500 tone/year (Tesfaye and Wolff, 2014). However, only 31% is being utilized. Here are some of the major findings in this review that water pollution challenges in Ethiopia lead to less utilization and accessible with regard to fish and fisheries.

Effluent discharges from the textile industries

Textile industries play significant role as domestic and national economy in the country. The effluents from the textile factories contain high amount of organic and inorganic chemicals and are attributed to high Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), pH, Total Suspended Solids (TSS) values, and low dissolved oxygen (DO) values as well as the color change of the given water body as reported by Abrehet et al. (2015). These make the textile industries one of the main sources of water pollution problems (Berehanu et al., 2015). For instance, a study made in Blue Nile River with respect to water quality parameters showed that the mean value of dissolved oxygen (DO) ranged from 3.7 mg/L at the site of waste water outlet of the Bahir Dar textile factory (Abrhet et al., 2015). Several studies also showed that dissolved oxygen level of textile effluents is low and varies from 0.42 to 4.60 mg/L, with mean values of 2.36 (Mohabansi et al, 2011), 4.8 - 8 mg/L (Sultana et al., 2009), 0.4 mg/L (Knat, 2012), and 0.28-5.12 mg/L (Abraha et al., 2014). The high value of the Biological Oxygen Demand (BOD) at the site of waste water outlet of the Bahir Dar textile factory is probably due to high content of organic load, and the high levels of BOD are also indicators of water pollution as documented by Abrehet et al. (2015) (Table 1). The authors have concluded that the textile factory (Bahir Dar) causes serious pollution to the aquatic habitat of the head of Blue Nile River. Therefore, there is a need to monitor (treatment) of the effluents before releasing into water bodies because these water bodies are important for the socioeconomic purposes such as drinking, fishing, bathing, and irrigation. Similar study was conducted at the Hawassa Textile Industry. The effluent contains severe toxic organic and inorganic compounds and this in turn can damage the aquatic biota including fishes. Based on the report of Lake Hawassa textile factory, effluent contains high COD (3 times higher), and TDS (19 times higher); moreover, PO_4^{3-}(39 times higher) was recorded in the textile effluent compared to the maximum permissible limit standardized by the Environmental Protection Agency (EPA, 2003) (Table 1).

The evidence is, the effects of textile factory effluents (5, 10 and 20% concentration levels) on the survival of tilapia fish fry killed high proportions of fish (65, 86.8 and 88.7%, respectively) compared to 16.1% mortality at 1% concentration level of the textile effluent. However, this is not quite different from that of the mortality rate in the control pond containing lake water of 9.4% (Berehanu et al., 2015). Besides, the consumption of the African big barb *Labeobarbus intermedius* whose catch is mainly from the rift valley lakes like Lake Hawassa and Lake Koka has declined. Desta et al. (2006) noted that the fish is found to be unsafe for human consumption due to its high mercury concentration, and the authors recommended

Table 1. Mean values of chemical parameters and some heavy metals in textile effluent reported by different investigators in relation to the maximum permissible limit prior to discharge to the environment (Zinabu and Pearce, 2003; Berehanu et al., 2015; Abay, 2007) at Hawassa textile factory and (Abrehet et al., 2015) at Bahir Dar textile factory.

Parameter	Berehanu et al., 2015	Abay, 2007	Abrehet et al., 2015	Maximum permissible limit (EPA, 2003)	Parameter	Berehanu et al., 2015	Gebre-Mariam and Desta, 2003	Maximum permissible limit (EPA, 2003)
Chemical Oxygen Demand (COD) mg/L	400	5183	-	120	Co (µg/L)	10.7	0.3	1000
Dissolved Oxygen (DO) mg/L	0.75	-	3.7	NS	Cr (µg/L)	2.3	17.7	1000
Nitrate (NO^{3-}) mg/L	5.3	17.8	-	50	Pb (µg/L)	28.1	0.4	500
Total Nitrogen (TN) mg/L	40	353.8	-	40	Cd (µg/L)	0.12	1.6	1000
Electrical conductivity (µS/cm)	3030	5455	1050	1000	Zn (µg/L)	41,000	8.9	5000
Phosphate (Po^{3-}_4) mg/L	386	9.84	-	10	Fe (µg/L)	1500	131.9	1000
Sulphate (SO_4^{2-})	0.052	136.3	-	200	As (µg/L)	0.69	10.6	250
pH (pH Units)	-	-	8.4	5 – 9	Hg (µg/L)	0.32	3.8	1.0
Temperature (°C)	-	-	25.2	40	-	-	-	-
Total hardness (mg/L)	-	-	88	NA	-	-	-	-
Total dissolved Solid (TDS) mg/L	1530	3818.5	612.3	80	-	-	-	-
Biological Oxygen Demand (BOD) mg/L	-	-	40.3	40	-	-	-	-

*NS-not specified, NA-not Available.

that higher Hg burdens significantly cause neurotoxin connected with human health and this is a result of poor water quality (pollution) caused by textile, ceramic and soft drink factories waste effluents discharged near the watershed of Lake Hawassa. Probably, high accumulation of mercury is associated with food chain. This dietary study on big barbs in different water bodies showed that the ingestion of detritus, sand particles and benthic food items indicates the ability of the species to live in benthic habitats and ingest sediments.

Effluent discharges from the tannery industries

The leather industry makes significant contribution towards economic growth, development, employment and generally poverty alleviation in the field of leather manufacturing. Nevertheless, it contributes huge amount of pollutants to the environment. For instance, total dissolved solid (TDS), Chromium (Cr), Sulphide, Chloride, total suspended solid, COD and BOD contribute 17000-21000 mg/L, 200- 250 µg/L, 240-300 µg/L, 9000 -11000 mg/L, 8000-10000 mg/L, 11000-13750 mg/L, 4600-5000 mg/L of the total pollution load of the Ethiopian tanneries per year respectively (Birhanu, 2017). The mean value of the parameters of the wastewater have shown that, majority of them were above the standard permit limit set by Environmental Protection Authority (EPA, 2003) (Table 2). Accordingly, excess pH of wastewater is not tolerable, e.g high pH values were recorded at Hora (10) and Gelan (11) tannery factories. Excess pH causes problems for aquatic life to survive in aquatic habitats (Birhanu, 2017) and fishes may die if $5 > pH > 10$. The remaining factories such as China - Africa, Friendship, Modjo, Farida, Colba, and Bahir Dar have pH values ranging from 6-9 based on the EPA standard guideline. The discharge of the total suspended solid (TSS) is higher in all factories compared to the maximum limit set by EPA (50 mg/L). In the same way, it is extremely higher at Friendship Tannery accounting for 3687.5 mg/L followed by Modjo Factory (2100 mg/L). Suspended solids are floating substances and have the ability to remain in water bodies under suspension. They can reduce the net primary production by blocking solar radiation (Utaile and Sulaiman, 2016). Phosphorus or phosphates are the main factors that influence the water quality, and the standard limit set by EPA is 10 mg/L. But, large amount of Phosphates is recorded at all tannery factories; it is extremely higher at Modjo estimated to be 215 mg/L

Table 2. Mean values of chemical and physical parameters in nine tannery factories effluent reported by different investigators in relation to the maximum permissible limit prior to discharge to the environment (Abrehet et al., 2015; Birhanu et al., 2017).

Parameter	Tanneries									Maximum limit (EPA, 2003)
	China- Africa	Friendship	Modjo	Hora	Mesako	Farida	Gelan	Colba	Bahir Dar	
pH	6.5	7.4	8.5	10	9	7.5	11	7.3	7.15	6-9
Total suspended solid (mg/L)	265	3687.5	2100	1520	690	1150	240	740	339	50
Phosphate (mg/L)	20.6	41	215	183	90	185	30	135	-	10
Ammonia (mg/L)	126.3	63.75	174	69	476	416	684	352	228	30
COD (mg/L)	1424	1700	6450	2605	3775	5950	3740	3650	850.8	500
BOD (mg/L)	1280	580	960	1840	1670	1900	2000	1480	342	200
Temperature (mg/L)	-	-	-	-	-	-	-	-	25.2	40
Sulphides (mg/L)	1.161	4.54	25.3	4.88	106.5	159	100.3	194	16.05	1
Conductivity (µS/cm)	-	-	-	-	-	-	-	-	3953	1000
Total dissolved solids (mg/L)	-	-	-	-	-	-	-	-	2003	80

followed by Farida comprising 185 mg/L and Hora consisting of 183 mg/L. The Ammonia (NH_3) values of the effluent discharges of the tannery industries are extremely higher than the EPA standard permit limit (30 mg/L). The recorded values range between 63.75 - 684 mg/L; however, higher values are obtained at Gelan factory estimated at 684 mg/L followed by Mesako accounting for 476 mg/L and Farid consisting of 417 mg/L of the total NH_3 load. The Biological Oxygen Demand (BOD) values range between 580-2000 mg/L; higher values were recorded at Gelan (2000 mg/L) and Farida (1900 mg/L) of the total pollutants discharged. The implication is the recorded high values of (BOD) are due to high concentration of organic pollutants. Discharging of the high BOD level into the environment has severe impact on aquatic biota including altering of water quality. This is because it promotes the growth of bacteria, which increase the demand of oxygen. This in turn decreases the concentration of dissolved oxygen, leading to mass mortality of aquatic organisms including fishes. Generally, the effluent from the tannery industries shows that the waste water effluents discharged into the aquatic environment are without or little adequate treatment. Excessive discharge of physic-chemical parameters like BOD, COD, TSS, phosphate and ammonia into the environment causes pollution in lakes, reservoirs and rivers. The potential environmental associated impacts include algal bloom (over algal biomass) and extreme poor water quality for the survival of river or lake aquatic system (Wosnie and Wondie, 2014; Birhanu, 2017) (Table 2).

Anthropogenic activities around water bodies and fish habitats

The Ethiopian lotic and lentic water systems are being exposed to serious ecological problems in relation to human activities (Temesgen and Getahun, 2016). Micro or macro habitat degradation is an urgent problem in most catchments of Ethiopian lakes and rivers. For example, 68.8% respondents around Lake Ziway said that the pollution of Lake Ziway is correlated with human activities (Desta et al., 2017). Of these, irrigation close to the shores or littoral zone of the lake (62%), deforestation at the watershed (57%), waste discharged into the lake (33%) particularly from Ziway floriculture industry, poor watershed management practices, particularly soil and water conservation activities (23%) are sources of water pollution. Based on the finding, the lake's fish stock is depleting through time and the possible challenges are water volume reduction due to water abstraction for irrigation and water supply (72%), siltation of the lake through soil erosion due to deforestation (71%), chemical pollution due to runoff from irrigated lands (65%), uncontrolled and excess fishing practices (54%) due to the increasing fishing population over time (86%), use of small mesh fishing nets (53%), lack of government control over fishing (31%), and lack of community involvement and sense of ownership of the lake (26%) (Desta et al., 2015). A study made in North-south gradient of Ethiopian lakes suggested that the major threats that contributed to the depletion of fish communities were overfishing, high sediment load and degradation of habitats (Vijverberg et al., 2012). Comparably, the diversion of River Awash for irrigation purposes (Abegaz et al., 2010), and water abstraction in Lake Zeway (Yohannes, 2003) and in Koka Reservoir (Hailu et al., 2010) for irrigation (during winter season) and floriculture are adversely impacting the water bodies. Moreover, municipal effluents (wastes) can affect the fish stock in Lake Hawassa (Fetahi, 2007). The sewage effluents consist of mixtures of chemicals like natural and synthetic hormones, alkyl-phenols, phthalates, bisphenol, pharmaceuticals and some pesticides (DDT). These chemicals interfere with the endocrine system of the fishes. Several adverse health effects in aquatic organisms have been attributed to developmental, neurological, endocrine and reproductive alterations (Dawodu et al., 2015).

Lake Hawassa has been exposed to environmental and ecological modification due to population growth and natural events. This is because around 50% of the water bed is filled with silt deposit and the lake's storage capacity has decreased by 4%. The morphometric changes of the lake are caused by anthropogenic activities like urbanization and agricultural activities around the watershed of the lake (Abebe et al., 2018). In the same way, the head of Blue Nile River is facing serious problem of waste effluents (discharges) from Bahir Dar City. Agricultural activities, deforestation, soil erosion, sedimentation, wetland degradation, eutrophication, toxigenic bacteria, invasive weed, over-exploitation of fishes, fecal pollution, climate change, improper solid and liquid waste management, stakeholders' conflict, lack of data base system, lack of environmental related policies and strategies and hydrological alteration are the recent challenges of Lake Tana (Gebremedhin et al., 2018; Goraw and Ayalem, 2017; Anteneh et al., 2010; Wondie, 2010). This is indirectly affecting the spawning site of *Laboebarbus* fish species that are endemic to Ethiopia (Anteneh et al., 2010; Wondie, 2010; Gebremedhin, 2014).Wetlands are a good site for fish production and they can also support other various aquatic organisms. Though, recently these water bodies are endangered due to several factors including human pressures, improper agricultural activities, nursery ground degradation, urbanization and industrialization and water diversion for irrigation throughout the Ethiopian wetlands (Hirpo, 2017).

Conservation of fishes and water bodies

Several authors documented that Ethiopia has 12 river basins, more than 9 lakes, more than 10 reservoirs or dams, more than 3 small water bodies or swamps (Janko, 2014; Hirpo, 2017). As seen above water bodies of more than 183 fish species harbor and collectively have the potential to produce 94, 500 ton/year (Tesfaye and Wolff, 2014). Of these, 31% is being exploited. The most common commercially important fish species are Nile tilapia, *Oreochromis niloticus*, the labeo *Labeo hori,* the African catfish *Clarias gariepinus, Barbus species* and the Nile perch, *Lates niloticus* (Tilahun et al., 2016). It is possible to observe that the expected fish yield exceeds the actual harvested fish product and therefore, management step up is critical to sustain fish products as well as the water bodies. Avoiding fishing during spawning grounds (Gebremedhin et al., 2014), mesh size restriction, reduced number of fisher men, balance catch quotas, banning beach seines, regulate illegal fishermen, equipment or chemicals, control of illegal fish traders, awareness creation on fish welfare and production through training, extension service by the concerned bodies are best management options for a better fishing strategy (Keliel, 2002; Temesgen and Getahun, 2016).

Conclusion

The Ethiopian fishery has faced multiple challenges. Challenges are caused by human induced and natural problem like the expansion of industrialization, poor land use practices, fish nursery (spawing) habitat destruction and agricultural practices. These challenges and problems should be addressed in order to sustain the fish and water resources for now and the next generation. The Government of Ethiopia needs to prepare and implement integrated water resources and fisheries management plan in the drainage basin of Ethiopia with full participation of all relevant stakeholders including the riparian community to sustain the water system in the basin.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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