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Agriculture is the most important sector in the Ethiopian economy, contributing the lion's share of the GDP. Nearly 80% of the population live in the rural areas and derive their livelihoods directly or indirectly from agriculture. Given its importance, the performance of the sector is therefore reflected in the performance of the whole economy. With this background, the Journal of Agriculture and Development aims to stimulate research and thinking on agriculture and development studies in Ethiopia. The articles contained in the journal reflect the views of their authors and do not necessarily coincide with those of the Editorial Committee, Institute of Agriculture and Development Studies, JADS or of SMU.

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CONTENTS

Potential Water Bodies to Develop FisheryResources in the Afar Regional State, Ethiopia

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Abstract

A baseline survey was conducted to generate information on the locations and fish production status of small water bodies and lakes in the Afar region. Eight natural lakes with surface areas ranging from 0.1 km^2 to 127 km^2 were surveyed. Most of the lakes are located along the belt of Awash River swamps. Data on water physico-chemical and biological parameters were collected. High water temperatures ranging from 27°C to 32.2°C were recorded in the surveyed lakes. Different fish species such as tilapia (Oreochromisniloticus), catfish (Clariasgariepinus), common carp (Cyprinuscarpio) and Lebeobarbus spp. inhabiting the Awash River were also found in some of the lakes that have a direct connection to the river. Despite the availability of commercially important fish species in the lakes, fishing has not yet been practiced. In situ measurements on water physico-chemical parameters indicated that the surveyed water bodies are suitable for capture fishery development. Developing capture fishery in these water bodies can thus contribute to curb the food insecurity and malnutrition problem of the region.

Keywords: Afar region, freshwater fish, lakes, morphometric features, water quality

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Introduction

Animal protein is considered to be rich in high-quality protein because of its essential amino acid composition and bioavailability. Animal protein contains essential amino acids including methionine, tryptophan, lysine, and isoleucine, which are often deficient in plant proteins. It is known that most of Africans including Ethiopian diets are based mainly on plants (cereals, pulses, tubers, fruits & vegetables) with limited inclusions of animal products. Fish comprises quality proteins and is a highly valued food item for its nutrient bioavailability. Besides providing quality protein, it has significant impacts on food and nutrition security. The value of fish and other aquatic products are well recognized in all parts of the world. As a result, development options targeting expansion of aquaculture and culture fishery to increase fish production and consumption have been suggested.

According to the Ethiopia Central Statistics Agency report (CSA, 2008), the Afar region has a population of 1.4 million, of whom 29.3 % are pastoralists. The livelihood of the people is mainly dependent on livestock rearing. The livestock population in the region includes camel, cattle, and sheep and goats as the dominant animal species. Most of the land surface is flat.The Danakil depression,the lowest and hottest place in Ethiopia and Africa is also located in the region. The geology of the area is known for its active volcanic features. The average environmental temperature ranges from 27-50 ºc. Overall, 70% of the area is classified as arid and semi-arid area, and 30 % as productive rangeland (MCE, 2001). The average annual rainfall is less than 200 mm. The rainfall is short and erratic in distribution.As a result, pastoralists are forced to trek their livestock long distancesto find water and grazing lands. There is always competition for scarce resources in the region such as water and grazing land during the drought season. Rivers, hot springs and lakes cover 1 % of the total areain the region. The water resources have been used for agriculture, salt extraction, domestic drinking and livestock watering (BoFED, 2006). Gashaw et al., (2011) reported the list of potential water bodies for fisheries development in the region; however, their contribution to fisheries has not yetbeenevaluated and used.

The country has huge fishery potential to expand the fishing sector in less exploited and unexploited water bodies like Lakes Gammari, Hertale, and Yardilocated in the Afar region. The region is located in a hot climate zone with suitable water temperature for fish growth and production. Thepresent study aims to assess the possibility of developing capture fishery in these

water bodies to contribute to achieving food and nutritional security and improve livelihoods in the Afar region.

Materials and Methods

Study area

The field survey was conducted in November 2015. Eight natural lakes were surveyed in Afar Region with surface area ranging from 0.1 km^2 to 127 km^2 (computed from Google satellite image).The study area coveredthe Awash River basin and associated lakes and isolated lakes such as Lake Afdera in Danakil depression and Lake Lomma - a small crater lake.The Awash River originates from the west central part of Ethiopia and has a catchment area of 112,696 km^2. The middle part of the river has several small to large sized lakes that have a direct connection to it.The recently constructed reservoir in the Awash river for sugar cane plantation know as Tendaho reservoir is not included in this study as it is already studied and well documented by Gashaw et al., (2011). The authors estimated the production potential, surveyed the fish species composition and limnological features of the reservoir. The location and some morphometric features of the studied lakesarepresented in Table 1.

Table 1. Location, altitude and surface area of surveyed water bodies in the Afar region

No.	Lakes	Co-ordinates	Altitude (m)	Area (km^2/ ha)	Remark
1	Afdera	13º13.208' N: 40 º 51.519' E	-104	127/12700	Hypersaline lake
2	Lomma	11º 57.905' N: 40º56.795' E; 25 km from Semera	360.8	0.5/52	saline crater lake
3	Gammari	11°31'06.3' N: 41°39' 05.2' E; 96 km from Semera	337.7	43.1	Located in the lower part of Awash River and have huge crocodile population
4	Hertale	09º 54.577' N: 40º24.278' E; 24 km from Gewane	579.3	14/1353	Macrophytes with clear water
5	Yardi	10º15.468' N: 40º31.691' E;37 km	562	88	Sandy beach, brown color, Flamingos
6	Liado	09º33.44' N: 40º11.450' E; 112 km Awash Arba	728.5	9.3/937	Shallow, brown color and used for domestic use
7	Detebed	09º34.294' N: 40º16.783' E; 113 km from Awash Arba	732.5	0.3/30	Small green crater lake
8	Alebelo	09º33.902' N: 40º16.286' E; 114 km from Awash Arba	732.5	0.1/7.5	Small green crater lake

Lake Afdera:lies in the northern part of the region, 104 meters below sea level. The lake is located 800 km away from the capital Addis Ababa. It has a maximum length of 25.99 km and a maximum width of 8.29 km. It is the second-largest lake in the region next to Lake Abe with an area of 127 km^2 and a mean depth of 60 m. The lake is used for salt mining and water is abstracted continuously.

Fig.1. Satellite image showing Lake Afdera, Afar region, Ethiopia

Lake Lomma: is a small crater lake located 43 km away from Semera town in the northwest direction. The lake has a surface area of only 0.5 $km^{2.}$ The maximum length of the lake at the rim ranges from 840 m to 940 m. It is situated at an altitude of 360.8 m above sea level. It is a closed system that has no clear water inflow and outflow. It is fed by surface runoff, groundwater, and hot springs. The total catchment area of the lake is 3.6 km^2. It is surrounded by a hill of crater rim in a circular shape and 155 m to 190 m high steep rocky slope rising above the lake.

Fig.2. Satellite image showing the catchment area of Lake Lomma, Afar region

Lake Hertale:is located in the west part of Meteka sub-urban in Gewane district; 18 km away from the town. The lake has a surface area of 14 km^2. Gewanetownwith around 12,000 inhabitants is located at the foot of Ayelu (also pronounced as Ayyalu) Mountain (2145 m high). The lake has an elevation of 579.3 m. a. s. l. and found along the belt of the Awash River. The east shore of the lake is impounded by a steep rocky mountain. It is a freshwater lake with growing macrophytes such as Phragmites and varieties of aquatic grasses in the shore area. Growing macrophytes are offering refuge for different juvenile fish and breeding habitats for various fauna. It is a home of different fish-eating birds, crocodiles, hippopotamus, and different fish species.

Lake Yardi:is also a freshwater lake in BureMudytuWoreda of Awash valley northeast of the region. It is 34 km away from Gewane town and located at an altitude of 562 m. a. s. l. The lake has 14.52 km maximum length and 8.05 km width with a surface area of 88 km^2. The satellite image indicated that the size of the lake and other swamps mainly depends on the discharge of Awash River in the summer season. The 2007 census indicated that the Woreda has a total population of 31,794 inhabitants, of whom 18128 are men and 13,666 women (CSA, 2008).

Lake Gammari:is located 96 km away from Semera town and 40 km far away from Asayita town in the east direction. It is situated at an altitude of 337.7 m. a. s. l. The surface area of the lake is estimated at 62 km^2. Lake

Gamari is a freshwater lake mainly fed by Awash River.The land on the east side of the lakeshore is very steep. The lake water looks clear in color and Secchi depth of 0.55 m. It is a shallow lake with a maximum depth of 3.7 m. There are large dead trees and wood stumps inside the lake. Crocodile, hippopotamus and different fish-eating birds are common. Despite the presence of crocodiles in the lake, the local people cross at the point where the Awash River and the lake joins. According to the people, the Lake Gamari crocodiles have not been attacking humans. The fish and other amphibian fauna are not well known in the area. The area surrounding the lakeis invaded with the fast-growing exotic invasive Prosopis plant species.

Lake Detebed:is found in zone 3 and 113 km from Awash Arba town. It is a crater lake surrounded by a plateau with a surface area of 0.3 km^2. It is a soda lake with a high concentration of $NaCO_3$. It is also a green lake and has no connection with the water source. According to local information, the lake contains fish and crocodile stocks. It also inhabited by different bird species but the lake has not been used for fishing yet.

Lake Alebelo: is found in zone 3 at DulesaWoreda of Afar region and 114 km far from Awash Arba town. The lake is located an altitude of 732.5 m. a. s. l and has a surface area of 0.1 km^2. It is a soda lake with a salinity level of 442 mg/l. It has closed catchment and the main water source of the lake might be precipitation and groundwater.

Lake Liado: is also found in zone 3 DulesaWoreda. It is located at an altitude of 728.5 m. a. b. s. l with a surface area of 9.3 km^2.It is 112 km away from Awash Arba town. It is a freshwater lake and the community used the lake for animal watering.The lake has a brown color with an attractive sandy shore. Fish, crocodiles, and hippopotamus inhabit the lake.

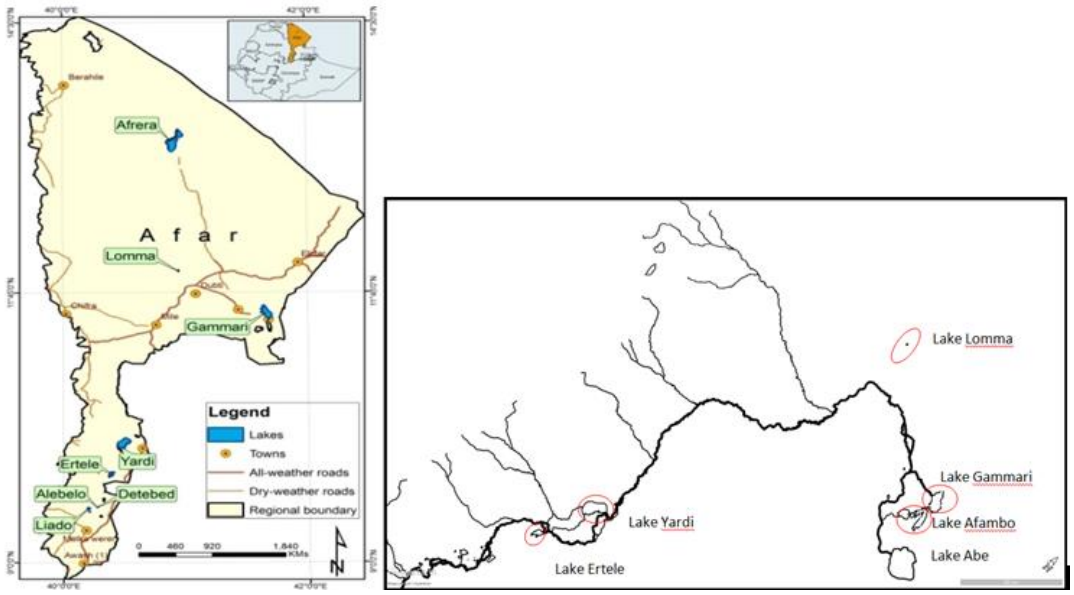

Fig.3. Map showing the location of natural lakes in the Awash basin and some isolated lakes (Lomma and Afdera), Afar region

Water sample collection and *in situ* measurements

Secondary information was gathered before the survey was conducted. Relevant documents and literature were reviewed. Three administrative zones around Semera and the surrounding area were surveyed. During the study, water samples were collected from each lake and transported to the NFALRC laboratory for further analysis. Some physico-chemical parameters of the water including conductivity, dissolved oxygen (DO), saturation, water temperature and salinity onshore area were measured with a digital multi-meter probe(Model HQ40d, HACH instruments). The physico-chemical parameters of each lake were measured and recorded at different times of the day.

The water samples were collected for plankton qualitative identification with plankton nets size of 30µm. Samples were immediately preserved in 5% formalin until examined in the laboratory. Plankton identification was done to genus and species level in the laboratory using a compound microscope and using different identification keys including those of Whitford and Schumacher (1973), Talling (1987) and Willen (1991).

Result and Discussion

The exact location and area of the surveyed lakes were not studied before. A lake with a salt concentration of 3g/L is considered as saline (Williams, 1983; Hammer, 1986). Hence, lakes in the Afar region can be categorized into freshwater and saline lake based on their salinity level (Table 2).

Among the eight surveyed lakes (Table 1), Detebed and Alebelo are soda lakes and small in size: 0.3 km^2 and 0.1 km^2, respectively. Soda lakes are characterized by a high concentration of carbonate salts and other dissolved salts. The main driving force that creates soda lakes is a geological condition that favors alkaline water and topography which restrict the surface outflow of water from the basin (endorheic). These two soda lakes are found close to each other and look deep green but have no diverse phytoplankton flora.

Lakes Afdera and Lomma are saline lakes with a salt concentration of 158g/L and 8.27g/ L, respectively. The location of Lake Lommais far from the main paved road and its route is known by local communities but never visited by scientific communities before. The people who are living around the lake frequently visit the lake to take bathing and massaging their body with a belief that bathing and swimming in hot springs has a healing power from diseases. Apart from this socio-cultural value, and its potential ecological value, the lake is not used for animal watering or salt mining. There is no available scientific information on its depth, surface area and physico-chemical characteristics before this study. The size of the lake was determined using satellite images during this study.

Lake Afdera is hypersaline and endorheic lake fed by hot springs and may be groundwater from the Red Sea (Gionfiantini, et al., 1973). Its salinity level is close to that of sea water and dominant ions in the lake are sodium chloride (Tenalem, 2009). The sodium chloride concentration is 158 g/L and there are large salt hills observed on one side of the lake. The high salinity level in the lake water might be resulting from evaporation and low precipitation in the area. Due to the high salinity level, it is used neither for fishery nor drinking purposes. Rather, it is used for commercial salt production. The total salt mining area covers around 2952 hectares of land and the average annual production level is reported to be 100,000 to 165, 000 tons of salt (Tenalem, 2009). The total dissolved solid of saline lakes (Chitu, Shala, Abijata, Abhe, and Asale) ranges from 20,000 to 50,000 mg/L, while freshwater falls in the range between 1000 to 2000 mg/L (Craig et al., 1977; Gizaw, 1996). Nevertheless, the lake is a habitat of two

endemic fish species of the Cichlidae family: *Danakiliafranchettii*and*CyprinodontidaeLabiasstiassnyae* (Getahun, 2001; Golubtsov*et al*., 2002). These species inhabit mostly the confluence between hot spring and the lake water. The fish species do not, however, grow big enough for consumption.

The Lakes Hertale, Liado, Gammari and Yardi are freshwater lakes found along the Awash river basin. Yardi looks brown in color and turbid. This turbidity might be linked to constant agitation and washing of sandy soil in the shore area. Lake Gammari has a huge potential for capture-based fisheries developmentthat has several economic and social advantages. The lake is located in a remote area that contributes to the limited attention given to it.

In general, though 50% of the surveyed water bodies are fresh and have a potential for fisheries development, there is little fishing activity in the region except inthe Tendaho reservoir where fishing started recently with the support of the regional pastoral and agro-pastoralbureau, the Ministry of Agriculture and the National Fisheries and Other Aquatic Life Research of the EIAR. The people who are living around the lakes use the water for watering their animals. They support different types of aquatic birds, flamingos, fish, crocodiles, and hippopotamus. The low fishing activity in the region could be due to either the feeding culture of the people and the poor extension service regarding fish production and consumption. Awash River flowing in the east direction has a direct connection to the freshwater lakes during the rainy season. The fish species such as tilapia (*Oreochromisniloticus*), catfish (*Clariasgariepinus*), common carp (*Cyprinuscarpio*), barbs (*Labeobarbusintermedius*) and Gara fish species that have been reported in the Awash river (Golubstov et al., 2002; Golubtsov& Mina, 2003) are also expected in all the four lakes as a result of the direct connection with the river.

Physico-chemical characteristics

The physic-chemical parameters of the surveyed water bodies are presented in Table 2. The water temperature varies between 27 °C to 32.2 °C, which is favorable for fish growth and production. The high water temperatures might be becauseof the location of the water bodies in low altitudes with high atmospheric temperature. Conductivity was between 695µS/cm to 250, 000µS/cm. Secchi disc depth reading was 0.5 m and 0.55 m in lakes Hertale and Gammari, respectively. The salinity level in LakesAfdera and Lomma were 8.27 g/L and 158 g/L respectively.The salinity level in the remaining

lakes surveyed wasbetween 0.664 mg/L to 674 mg/L. The physico-chemical characteristics of the reservoir and lakes in Afar are found to be favorable for warm water fish species including tilapia, catfish and common carp.

Table 2.Physico-chemical parameters of surveyed water bodies in the Afar region

No.	Water bodies	Temperature (ºC)	Cond. (µS/cm)	Parameters		Salinity
				DO (mg/L)	Saturation (%)	
1	Afdera	32.2	250,000[a]	8.06	109.6	158 g/L [b]
2	Lomma	32	16540	7.0	99.1	8.27 g/L
3	Hertale	27.9	1434	6.53	89.8	674 mg/L
4	Yardi	27.4	1554	8.61	116.5	350mg/L
5	Liado	30.3	1460	6.44	93.8	664 mg/L
6	Detebed	29	-	3.16	45.4	2.26 mg/L
7	Alebelo	28.8	965	7.35	104.4	442 mg/L
8	Gammari	33.3	2390	6.8	93.3	0.663 mg/L[b]

Sources: a = UNDP, 1973; b = Gasse, 1987; LERUP, 2001; the remaining values were *in situ* measurements of the present study

Plankton diversity

In tropical natural water bodies, the main driving force in plankton diversity are dry and wet seasons, which bring change in the water column and biota (Sondergaars, et al., 1990; Nderbele-Murisa et al., 2010). There was no zooplankton community in LakeAfdera which might be due to the high salinity levels. Only a few blue-green algae species were identified in the water samples collected from other lakes (Table 3). Blue-green algae are dominantin the soda lakes; mainly*Microsists*were found in LakeAfdera. The low phytoplankton diversity in the lake might be related to water chemistry and high salinity levels. Some blue-green algae such as *Arthrospira*, *Anabaenopsis*, and *Chroococuss* are well adapted to saline-alkaline lakes, but not found in the survey water bodies. The phytoplankton diversities in the lakes could be used as natural food and have a direct contribution to fisheries productivities in culture based fisheries (Lorenzen, 1995; Li &Xu, 1995; DeSilva, et al., 2006). The biodiversity of fauna and flora decreases as salinity level increases outside the normal range (Vareschi&Vareschi, 1984). The Zooplankton community in LakeLomma is dominated by

Copepod groups. Only *cyclopoidcopepodas*and*nauplii*were dominant and few macro invertebrates' taxa *Chorixidae* and *Chironomidae* were also identified in the study. C*hironomidae*is the only organism that can live in the shore of anoxic and soda lakes and exploit the available food in the margin (Tudoranca, et al., 1988). Lake Hertale is oligotrophic which means low nutrient level and phytoplankton biomass. Zooplankton composition of the lake is dominated by copepods and rotifers which are common in tropical lakes and reservoirs. Among the Copepods group, *Nauplii*and*cyclopoids* are dominant while in rotifers, mainly on *Keratella*, *B. calciflorus, B. falcutus,* and *B. caudatus*were common.

Table 3. List of zooplankton identified from six sampled water bodies

Zooplankton groups	Species	List of water bodies					
		Lomma	Hertale	Yardi	Liado	Detebed	Alebelo
Rotifera	*Asplanchina*	-	+	-	-	-	+
	Alonaspp	-	-	+	-	-	-
	Keratellatropica	+	+	+	+	-	+
	B.caudatus	-	++	-	-	-	-
	B.falcatus	-	++	-	-	-	-
	B.calciflorus	-	++	+	+	-	+
	B.angularies	-	-	-	-	-	+
	Filliniaopolinsis	-	+	+	+	-	-
Copepoda	*Nauplii*	++	++	+++	+	+	+
	Cyclopoid	++	++		+	+	+
Cladocera	*Diaphanosoma*	-	-	+	+	-	+
Macro invertebrates	*Water boat (corixidae)*	+	-	-	-	-	-
	chironomidae	++	+	-	-	+	-
	Chironomidae pupa	-	-	+	-	-	-
	Chironomidae Larvae	-	-	+	-	-	-
	May fly	-	-	-	+	-	+
	Midge fly	-	-	-	-	-	+
	Cowborus	-	-	+	+	-	+
	Round worm	+	-	-	-	-	-

Note: absent during investigation, + means present during investigation, and ++ means abundant.

Conclusions and Recommendations

Eight water bodies were observedduring the survey period. Four lakes are fresh, two are soda and the remaining 2 are saline. Lakes Afdera, Hertale, Yardi, and Gammari were closely assessed and the existence of fish was confirmed, whereas the rest of the lakes have not been assessed for the availability of fish fauna and diversity. Hence, further investigation on fish stock, diversity, and other biology parametersis needed. Among the water bodies studied, Lake Afdera is a hypersaline lake and inhabited by two endemic fish species. Due to the high salinity level, it is used for salt mining and tourism purposes only. Fishing has not been started in the region despite the presence of suitable water bodies. So, awareness should be created at different levels to exploit the untouched fishery resources. Some of the visited lakes are hyper saline while others have a high population of crocodiles thus not suitable for fishing. Fishing in LakeGammari and Yardi needs caution due to the high number of crocodiles. Lakes Abaya and Chamoin the Southern Nations, Nationalities and peoples Regional State (SNNPRS)-also have huge crocodile populations, their fisheries are, nevertheless, well developed.

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