Research Article

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Assessment of the status of lake afdera in the danakil depression; afar, Ethiopia

Abstract

Lake Afdera is a supper saturated saline Lake located in the Danakil Depression, lying below a sea level with the lowest point at –120m. It is a major source of salt extraction in Ethiopia, where the Lake water is pumped to saltpans for solar evaporation. This study was conducted to generate basic information on the impacts of salt mining on the Lake ecology and its biotic resources as well as the surrounding hot springs. Purposive sampling method with semi-structured questionnaire, and focus group discussions were used to generate data. Results indicated that excessive water pumping, pollution, deforestation of lakeshore vegetation and climate change are the most important threats to the Lake and its biodiversity. Majority of the respondents are aware of the negative impact of salt extraction on the Lake and its biodiversity. Because of the absence of lack of awareness and alternative sources of livelihood, however, they still are comfortable to continue business as usual. The absence of active roles of the government and NGOs engaged in the areas of conservation and sustainable use of biodiversity has contributed for over-exploitation and misuse of the resources in the area. Therefore, conducting regular awareness raising and environmental education activities, adoption of restrictive use of resources as well as creating alternative livelihoods and selected nature reserves at carefully selected Lakeshores are of paramount importance to save the Lake and its biodiversity before its eventual demise.

Keywords: lake afdera, salt mining, hot springs, endemic species

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Misikire Tessema, Takele Shitaw, Birhanu Beyene, Berhan Asmamaw, Abraham Assefa
Ethiopian Biodiversity Institute, Ethiopia

Correspondence: Abraham Assefa, Department of Animal Biodiversity Directorate, Ethiopian Biodiversity Institute, Ethiopia, Email abiab1975@gmail.com

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Introduction

Lake ecosystems are areas where plants, animals and microorganisms co-exist in harmony. They are vital ecosystems for aquatic, wildlife and human needs for multitudes of goods and services such as sources of drinking water, fisheries, water for irrigation, industrial activity, recreation, and cultural and scientific needs. Any changes in quality of physical, chemical and biological properties of lake ecosystems may have wide ranging ecological and societal implications.

Extraction of salt from the lake/sea waters by evaporation in solar ponds leaving salt crystals is an effective method of producing salt in areas of high evaporation and low precipitation.[1] More than one third of the salt production worldwide is achieved by solar evaporation of sea water or inland brines.[2] Lake Afdera is located in the Danakil Depression in the Afar region, Ethiopia, and lies below sea level with the lowest point at –120m.[3] It is super saturated saline Lake, and has been serving as the major source of salt extraction in the country, whereby water is being pumped out from the lake to the saltpans that have been constructed around the Lakeshores and sometime far away using underground pumps. The lake is fed by numerous hot springs that are found around its shores. These hot springs and the Lake are habitats for different fish species, including the endemics *Danakilia franchettii* (belonging to the genus Danakilia) and *Aphanius stiassnyae*, (belonging to the genus Pupfishes and formerly known as *Lebias stiassnyae*) which, according to IUCN,[4] are endangered. Unfortunately, the ongoing salt mining activities are threatening the existence of the Lake and its biodiversity. The hot springs are being destroyed to transform the area for the creation of saltpans and the building of stone walls, which in some instances are used to separate the concessions.[5] Very few research works have been conducted in Lake Afdera so far. This may, among others, be due to its distance from the center of the country where many aquatic researches are coordinated, harsh climatic condition of the area and absence of economically important fish species in the Lake. Because of this, clear and up-to-date information on the Lake and its aquatic biodiversity is extremely scarce. Therefore, this assessment was conducted to generate basic information on the impacts of salt mining on the ecology of Lake Afdera, its biotic resources and the hot springs feeding the Lake.

Methodology

Data from the study area were collected in two rounds, on December 2017 and April 2018. On the first round of data collection, reconnaissance study on the physical Lake ecosystem as well as salt mining activities was conducted, and on the second round, similar activities carried-out in round one as well as socio-economic data from respondents residing around the Lake were collected.

In this study, therefore, Purposive sampling with semi-structured questionnaire, and focus group discussions methods were used to study the socioeconomic aspects of the respondents, and their perceptions about the impact of salt mining activity on Lake Afdera and its biodiversity. Purposive sampling is a non-probability, also known as judgment, selective or subjective sampling method and it occurs when elements selected for the sample are chosen by the judgment of the researchers.[6] This method can be used when the researchers believe that representative sample is obtained with sound judgement. Thus, purposive sampling was used in order to identify those people who are in a close contact with the Lake, and focus group discussions with elderly people were conducted to generate data on the current status of the Lake and its biodiversity. Field observations were made to assess the numbers and sizes of saltpans, the amount of spoiled salt, waste disposal methods of the salt miners and tourists on the Lake as well as its surrounding hot springs.

Description of the study area

Lake Afdera is located in Danakil Depression in the Afar National Regional State (13.2°N and 40.9° E) at an altitude of -111m below sea level,[5] and has a surface area of 140km^2.[7] It is supersaturated saline Lake and is home for at least two endemic fish species.[8] According to Chiozzi et al.[5] average salinity, temperature, oxygen, latitude and longitude of Lake Afdera are 130.25 (g/lit), 30.5°C, 5mg/lit, 13.22092 and 40.87407, respectively.

The study on the socio-economic aspects of the respondents was conducted in Afdera wereda (in Zone 2) of the Afar National Regional State. Two *kebeles*, namely: Aligenda (N=59) and Adaela (N=33) that are bordering the Lake were systematically selected for the study (Figure 1). Afdera wereda has an area of 7,435.45 km^2. The total population of the wereda is 32,225, of which 18,191 are men and 14,034 are women. It has a population density of 4.33. A total of 4,803 households exist in the wereda, which results in an average of 6.7 persons per household. Of the total human population, 98.6% are Muslims, and 1.34% are Orthodox Christians.[9]

Data analysis

Descriptive statistics was carried out using SPSS version 16 to analyze the data. A graph depicting percentages of respondents and major threats to the Lake was sketched with the same software. The study area was mapped with ArcGis 10.

Result

Socio-economics aspects of the respondents

In this study, 92 residents of the two *kebeles* were randomly selected and interviewed. Out of the total respondents, 70 (76.1%) were males and the remaining 22 (23.9%) were females. The age groups, marital and educational status as well as the occupation of the respondents involved in the study and number of years, they lived in the study areas have been summarized in Table 1. As indicated in the Table, majority of the respondents are found in 29-39 age groups and whereas 65 (70.7%) of the respondents are married. The number of household members of the respondents ranged from 1 to 13, with an average of 4.05 (SD 2.442). The educational status analysis revealed that most of the respondents were classified either as illiterate (26.1%) or had an informal schooling (40.2%). Out of the total respondents (81, 88%) were Muslims and the remaining (11, 12%) were Orthodox Christians. The dominant occupations of the respondents were salt farming (59, 64.1%) followed by animal rearing (26 28.3%).

Table1 Socio-economics characteristics of the respondents

S.No	Age category			Marital status			Educational status			Occupation			Years respondents lived in the study area		
	Age group (years)	No.	%	Group	No.	%	Group	No.	%	Group	No	%	Years lived	Res-pon-dents	%
1	18-28	38	41.3	married	65	70.7	illiterate	24	26.1	salt farming	59	64.1	1-20	67	72
2	29-39	44	47.8	single	21	22.8	informal schooling	37	40.2	animal rearing	26	28.3	21-40	20	21
3	40-50	7	7.6	divorced	1	1.1	primary & secondary schools	21	22.8	civil servants	4	4.3	41-60	5	5.4
4	50	3	3.3	widowed	5	5.4	preparatory school	9	9.8	house wives	3	3.3	-	-	-

The results of the study indicated also that, out of the total of 92 respondents, 81 (88%) are living in a distance that takes them less than 30minutes' walk from the Lake. The remaining (11, 12%) live in an area which takes 31-60 minutes of walk to reach the Lake. Most of the respondents (64, 69.6%) were not a member of any organizations that work on environmental issues. Only 28 (30.4%) responded that they are members of some organizations working on environmental protection aspects. Majority of the respondents (84, 91.3%) replied that they will benefit from the salt mining activities, if the lake ecosystem is maintained and protected well. However, only 7 (7.6%) and 1 (1.1%) of the respondents said that they get a benefit from wildlife habitat and recreation, respectively. Out of the total, 89 (96.7%) respondents replied that they have never been consulted by anybody for the management of the Lake and its ecosystem so far. However, 3 (3.3%) of the respondents replied the other way. Similarly, 89 (96.7%) respondents replied that they didn't know whether the lake is home for any endemic fish species.

Out of the 92 respondents, 62 (67.4%) replied that they know that habitats of fish species of the Lake are being threatened, while the other 30 (32.6%) didn't realize whether the threat existed at all. The result of this study showed also that 33 (35.9%) of the respondents has high concern on the condition of the Lake ecosystem and they need to see sustainable management of the lake ecosystem and its biodiversity for the benefit of the next generation (Table 2).

The major threats of the Lake ecosystem listed by the respondents were over-pumping of water for salt extraction, pollution, deforestation of Lakeshore vegetation and climate change (Figure 1). When requested whether the benefits accrued from salt extraction are better than the Lake's ecological services, 70.7% of the respondents strongly agreed, but 16.3% disagreed.

The major negative impacts of salt extraction activity on the Lake ecosystem are identified as loss of biodiversity, pollution, formation of sinkholes and soil erosion, in order of importance (Table2).

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Table 2 Knowledge and concern of the respondents on Lake ecosystem and its biodiversity

S.No	Knowledge on:						Opinion on benefits gained from salt extraction compared to ecological services			Negative impacts of the salt extraction activity on the Lake ecosystem		
	existence of threats on the Lake ecosystem			the current status of the Lake ecosystem								
	Status	No.	%	Group	No.	%	Group	No.	%	Group	No.	%
1	realized the threats	62	67.4	highly threatened	56	60	strongly agreed	65	70.7	loss of biodiversity	54	58.7
2	not realized	30	32.6	least threatened	24	26	disagreed	15	16.3	pollution	30,	32.6
3	highly concerned	33	35.9	not threatened	12	13	strongly disagreed	9	9.8	formation of sinkholes	5	5.4
4	least concerned	37	40.2	-	--	-	agreed with the idea	3	3.3	soil erosion	2	2.2
	not concerned	22	23.9	-	-	-				no impact at all	1	1.1

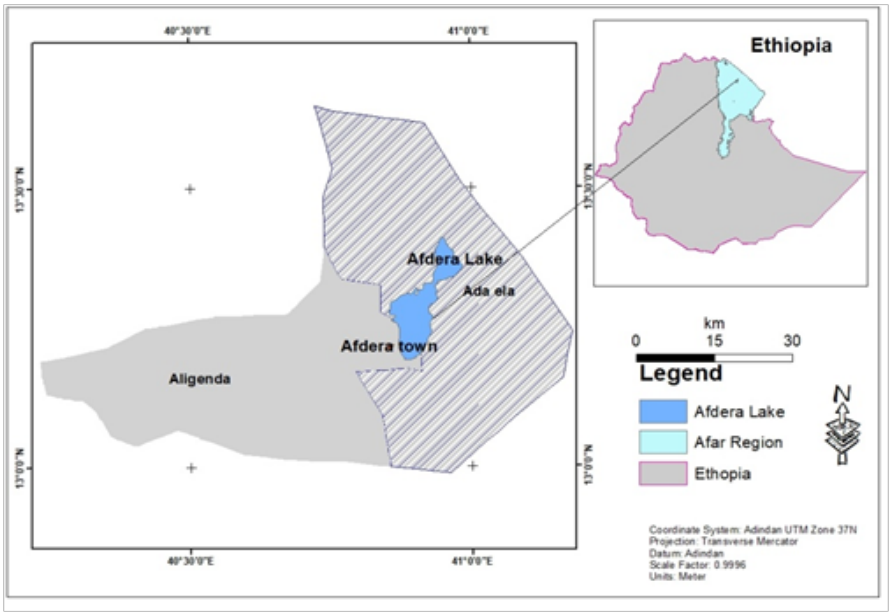

Figure 1 Map of the study area.

The respondents indicated further the nature of the impact of salt extraction on the Lake ecosystem as negative, neutral, and positive. Sixty five (70.7%) out of the total of 92 respondents who recognized the negative impact of salt extraction on the Lake ecosystem, classified the extent/scale of the impact as specific, local, regional, national and international (Table 3). According to these respondents, duration (life time) of the impact of salt extraction on the Lake ecosystem was categorized as short term, medium term, long term, and permanent.

The intensity/magnitude of the impact of salt extraction on the Lake ecosystem was also prioritized as low, medium, high, and very high (Table 3). Regarding the degree of negative impact of salt extraction on the Lake ecosystem, the respondents indicated the impact as definite (27, 29.3%), highly probable (39, 42.4%), probable (18, 19.6%), and improbable (8, 8.7%). The reversibility of the negative impact of salt extraction on the Lake ecosystem, in the same manner was listed by the respondents as follows: complete (35, 53.8%), intermediate (29, 44.6%), and not possible (1, 1.5%).

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Table 3 Nature, extent, duration and magnitude of the impact of salt extraction

S.No.	Nature			Extent/scale			Duration (life time)			Intensity/magnitude		
	status	No.	%	group	No.	%	group	No.	%	group	No.	%
1	negative	65	70.7	site specific	28	43.1	short term (<5 years)	4	6.2	low	6	9.2
2	neutral	20	21.7	local	18	27.7	medium term (5-15 years)	6	9.2	medium	9	13.8
3	positive	7	7.6	regional	12	18.5	long term (>15 years)	35	53.8	high	14	21.5
4				national	5	7.7	permanent	20	30.8	very high	36	55.4
				international	2	3.1						

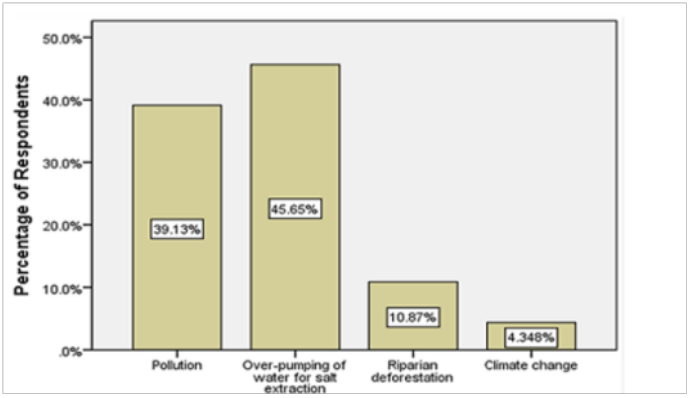

Figure 2 Major threats to Lake Afdera ecosystem.

Discussion

Salt extraction is the main source of income for the community residing around Lake Afdera. Currently, high scale salt extraction activities are underway in the southern, south eastern and western shores of the lake where artificial saltpans, salt mounds, underground water pumps and associated structures to the recently constructed saltpans at distant areas. The extent of these modifications is visible from field observations at *in situ.*

Respondents involved in this study were mainly within the working age (<40 years) and are married, with an average household member of 4.05 (SD 2.442). This high number of average household members indicated, that they are almost totally depending on this very economic activity followed by livestock rearing, indicating the extent of pressure being exerted on the Lake ecosystem. On top of that, more than 26% of the respondents are illiterate, possibly with no or little knowledge about the need for environmental protection, live in a very close distance from the lake exacerbating environmental degradation. Besides, it was found that nearly 70% of the respondents were not a member of any organizations working on environmental issues, worsening the situation. People working for the salt extraction companies have no proper sanitation facilities, so they are using the hot springs to wash their clothes and keep their personal hygiene, thus; threatening the existence of hot springs and biodiversity therein.

Hot springs are the main sources of water, feeding Lake Afdera. Moreover, the hot springs are homes to endemic fish species as well. Practical knowledge of the respondents on the uses of the Lake ecosystem other than salt mining is very poor, indicating that there is a strong need for raising awareness and provision of trainings on basic biodiversity conservation and sustainable use issues. More than 96% of the respondents even had no clue about the existence of endemic fish species in the Lake ecosystem. Findings of this study indicated also that the respondents had never been consulted by anybody regarding the management of the Lake and its ecosystem; indicating ineffectiveness of the government, NGOs and other civil society organizations working in environmental conservation. The findings of this study indicated also that 67% of the respondents are well aware that habitats of fish species of the Lake are being threatened, and even 35% of them are highly concerned about the continuity of the existence of the Lake ecosystem and its biodiversity to the next generation.

The respondents have prioritized the major threats Lake Afdera ecosystem is facing, which are also reported as one of the major threats in other salt mining areas. Over-pumping of water for salt extraction is considered as a major threat for the Lake. Currently, dozens of pumping stations drive salt water out of the Lake to the nearby artificial saltpans for eventual solar evaporation. Observations at in situ indicated that, due to ever increasing number of salt miners and the resulting shortage of land in the nearby Lakeshore areas, salt miners have started to pump Lake water using underground pumps to distant areas where they have constructed new saltpans. Consequently; water pumping in the long term, can result in the lowering of the lake level as over-pumping of the Lake water to the saltpans is not counter balanced by the input of water to the Lake. According to Enrico et al.[10] Lake Afdera's level appears to have dropped by over 10m–20m during the last half a century. Recently; the surface of the lake, measured by satellite altimetry, was -112m below sea level Enrico et al.[10] In 1969, the Lake's surface was estimated at 90m to 100m below sea level.[11] From this information, Enrico et al.[10] concluded that the Lake's surface has dropped by 10m to 20m within half a century, continuing a desiccation trend that started several thousand years ago. Lake Alemaya, that was found in the eastern part of Ethiopia, and was used as the source of Nile tilapia (*Oreochromis niloticus*) and Catfish (*Clarias gariepinus*) for the local communities, dried out completely, mainly because of over-pumping out the lake water for irrigation of the commercial crop known as khat (*Catha edulis* in the area and sedimentation,[12] that is a painful experience, people need to learn from it.

Pollution is found to be the second most important threat to Lake Afdera whereby salt miners are using the hot springs as their site of

sanitation and laundry facilities, highly threatening the endemic fish species of the Lake. Habitat fragmentation, which is a landscape-scale process involving both habitat loss and the fragmentation of habitat,[13] is the other major threat to the Lake Afdera. Unregulated salt extraction can result in an overall loss of salinity of the Lake, with unpredictable effects on its general ecology. In particular, the decreased salinity could trigger a remix of *Danakilia franchettii* populations, which are now separated in different springs and currently kept apart by the elevated salinity of the Lake, which is nearly ten times higher than that of the hot springs Chiozzi et al.[5]

The salinity of lake Afdera dropped from 158g/l in 1968,[11] to 130 g/l in 2016 Chiozzi et al.[5] while the saltpan coverage over most of the area is possible cause of the disappearance of many thermal springs and of some fish populations.[8] The use of vast amounts of land for saltpans and consequent destruction of the hot springs had also a great impact on the natural Lake shore vegetation composed of salt tolerant plants such as doum palms (*Hyphaene thebaica*), *Tamarix sp*. and *Carex sp.* which, however, are currently missing over most of the Lake shore areas. Ecological impacts of fragmentation and removal of vegetation has been reported for a number of coastal areas and wetlands. According to Donald et al.[14] removal of vegetation by beach grooming and channel dredging created conduits for pelagic water to infiltrate the marsh and disrupt the ambient chemical/physical conditions. Alterations to both fish and macro-invertebrate communities were also evident where significant amount of vegetation was removed. According to Mineo Consortium,[15] mining affects the environment and associated biota through the removal of vegetation and top soil, displacement of fauna, release of pollutants and generation of noise.

Climate change is considered by 4% of the respondents as another threat to Lake Afdera ecosystem, though the impacts cannot be ignored. An elevated ambient temperature, which is being used as a means to salt mining, is believed to have the same effect on the Lake as well by negatively affecting its water level. According to Parry et al.[16] lakes that are currently permanent in arid and semi-arid regions are likely to shrink and may even become ephemeral in the future. According to IPCC,[16] the combined effect of increased evaporation due to higher temperatures and the predicted large-scale regional changes in runoff and precipitation will have profound consequences for salt lakes.[17]

The new asphalt road connecting Afdera village to the capital of the country (Addis Ababa) via Djibouti road greatly facilitates the transit of trucks and inflow of new job seekers, thus making salt trade a more lucrative business than in the past. This could dramatically increase salt extraction in the area. A rampant growth of human population (salt miners and other workers, shop owners, tourists, etc.) and better road connectivity is also exacerbating the already existing challenges of pollution (sewage, dumping, etc.) that can affect the ground water aquifer, the springs, and ultimately the Lake.

This study has also attempted to figure out perceptions of the respondents about the impacts of salt extraction on the Lake ecosystem. In this regard, the results indicated that though the benefit accrued from the salt mining activity looks obvious, more than 70% of the respondents are found to be well aware of the negative impact of salt extraction on the Lake ecosystem; and loss of biodiversity, pollution, sinkholes formation and soil erosion were indicated as major negative impacts. This indirectly indicates that the respondents are conscious of the negative impacts of salt extraction in the study area. Attributed to absence of any alternative livelihoods, however, they are keeping on salt mining, even if they know that the activity is unsustainable with the expectations that the extent/scale of the impact is only site specific.

Conclusion and recommendation

Lake Afdera is a supper saline lake found in the Danakil Depression, Ethiopia. It is home for endemic fish species *Danakilia franchettii* and *Aphanius stiassnyae* and other living organisms. However, the intensive and semi-industrialized salt mining in and around the Lake is threatening the existence of the Lake and its biodiversity. Loss of high amount of water from the Lake, damage to the natural lakeshore vegetation, pollution and landscape dilapidation are the most important threats to the normal functioning of Lake Afdera ecosystem, calling for urgent interventions. One of the most important measures to be put in place is the adoption of restrictive regulations. The salt extraction companies are currently over-exploiting the southern, south eastern and western banks of the Lake, and areas far from the Lake shores through underground pumps. Observations *in situ* indicated that only the northwestern and northeastern banks have not yet been exploited by the salt industry. The later areas are not only easily inaccessible to the salt miners but also the rugged terrain of those areas might not be suitable for construction of saltpans easily. Therefore, it might be a matter of time until intensive exploitation will reach to these areas. A possible solution to keep these areas intact is creation of some reserves where human activity, apart from traditional pastoralism, is restricted. However, multidisciplinary field surveys are required in order to come up with recommendation on those specific areas, including their ecosystem services that should be selected for conservation sites. Awareness raising activities and environmental education as well as creating alternative livelihood options should be given a priority at the earliest time possible, without waiting for the outcomes of the above multidisciplinary field surveys. Observations in the field indicate also that some of the salt that has been produced simply remains uncollected causing unnecessary loss of resources and spoilage of Lakeshore terrestrial environments, calling for regulations that restrict the level of salt mining and sustainable use of the Lakes' other abiotic and biotic resources.

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Conflicts of Interest

No conflict of Interest among the Authors.

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