Heliyon

Assessment of post-harvest fish losses in two selected lakes of Amhara Region, Northern Ethiopia

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Abstract

Fisheries play a significant role in food security, livelihood, and source of income in developing countries. The annual fish production potential of Ethiopia reaches up to 51, 000 tones, however, the actual production is much less than the potential that the country has. The fisheries sector of Ethiopian is not well developed regarding pre and post-harvest handling practices. Besides, post-harvest loss in the fisheries sector is not yet well-studied. This study objective aims to assess causes and extent of post-harvest loss associated with fish in Lakes of Hayq and Tekeze. Post-harvest loss assessment was conducted using a simple random sampling approach from October 2017 to May 2018. The study was conducted based on FAO recommendations of qualitative and quantitative field assessment methods. These methods include Informal fish loss assessment method (IFLAM), load tracking (LT) and the questionnaire loss assessment method (QLAM) methods were used to assess the causes and to estimate the amount of PHL of fish. The data generated by these methods were analyzed descriptively as well as a GLM model was used to understand the causes of fish loss in the two study lakes. A total of 140 randomly selected participants were included in the interview process. From these participants, 85 of them were from lake Tekeze while the rest were from Hayq. Results indicate that high environmental temperature,

absence or delayed marketing, harvesting immature fish, predators, and flood are the most important causes of post-harvest loss of fish in the two Lakes. Besides a GLM model predicted that study lake, boat type used, boat ownership, species of fish harvested, preservation method used, distance to market (Km), Maximum catch/day (Kg), Minimum catch/day (Kg), and Fishing experience were essential predictors for post-harvest loss incurred by fishermen on daily basis. Based on secondary data from agricultural office, the monetary value of the post-harvest loss of fish was estimated to be 10,934,000 Ethiopian birrs (397,600 USD) for the last six years in the study areas. A considerable product loss in the fisheries sector indicates the need for intervention by stakeholders. Provision of support services and assets such as freezers, electricity generators, boats, legal net and on job training about proper handling practices may play a tremendous role in decreasing post-harvest loss in the fisheries sector of the study areas.

Keyword: Agriculture

1. Introduction

Fisheries play a significant role in food security, livelihood, a source of income and social development in developing countries (Hossain et al., 2015). The massively grown demand for animal protein and improved technologies in the sector played a significant role for the industries growth. World per capita fish supply grown rapidly in the last decades and bypass world population growth (Garcia-Rodríguez & De La Cruz-Aguero, 2011). The aquaculture sector played an important role in the fisheries sector rapid growth. Small-scale fisheries operating mostly in the developing countries accounts half of the total fish production globally. These small-scale fisheries are facing many challenges these days. These challenges include post-harvest losses (PHL, illegal fishing, and over fishing (FAO, 2016).

As one of the, most limiting constraint of the fisheries sector, PHL indicates a fish that is either discarded or sold at a lower price due to many factors. PHL require a great concern because it is a loss of an essential animal protein that should be consumed or sold in a faire price. It causes a massive economic loss to fishermen, and traders globally (Diei-Ouadi and Mgawe, 2011). The most frequent types of PHL are physical loss, quality loss, nutritional and market force loss (Ahmed, 2008; Diei-Ouadi and Mgawe, 2011). Among many reasons, High environmental temperature, extended storage without preservatives, predators, insect infestation, increased production and lack of market are the main causes of PHL (Tesfay and Teferi, 2017).

Ethiopia has many natural and man-made water bodies that harbor more than 183 fish species. These water bodies represent 7334 km^2 of lakes, 275 km^2 of small water

bodies and 7,185 km of rivers. The total fish production potential is estimated to be 51000 tons/year. However, the countries per capita fish consumption remains one of the lowest in the world which is around 250g/individual/year. Currently the country's demand for fish exceeds supply fourfold (Kebede and Gubale, 2016).

Even though the country has massive potential of fish production, the sector is still in its infantry stage regarding pre and post-harvest handling practices. Post-harvest loss of the production is not yet estimated, and the causes of postharvest production loss are still less understood. These production problems are expected to be massive because of several factors. These include but not limited to the competence level of fishermen, the type of boat and gears they use, availability of cold chain storage facilities to keep the product, limited access of market by producers, among others. If fishers and policymakers were to be able to make informed decisions to reduce PHL levels, then tried and tested methodologies should be investigated. Such methods have not been available mainly because of the difficulties associated with assessing the loss in multi-species fisheries and the problem of measuring quantities of fish under survey conditions. The assessment of potential causes of post-harvest loss in harvested fish is very crucial to ensure the safety of consumer and efficient utilization of the sector (Ahmed, 2008; Tesfay and Teferi, 2017).

The post-harvest loss in fisheries due to poor handling practices is one of the most significant challenges for developing countries. A recent study showed that if Ethiopia was to put measures to reduce PHL in fisheries, the sector could contribute a minimum of 1.7% to the national GDP (Tesfaye and Wolff, 2014). Because of PHLs, the contribution of the fisheries sector to the country's economy is negligible. In recent years, the fisheries sector has drawn the attention of governmental and non-governmental organizations involved in fisheries and related activities. Therefore, this study was designed to identify the causes and estimate the monetary value of fish post-harvest loss at Lake Hayq and Tekeze reservoirs.

2. Materials and methods

2.1. Study areas

The study was conducted in Amhara region in Northern Ethiopia within the surrounding of Tekeze man-made reservoir and Lake Hayq. The reservoir is built on the Tekeze river which is a tributary of the Nile. The Dam has an average area and depth of 160.4 km^2 and 58 m respectively (Teame et al., 2016). It has a tremendous resource regarding fish production that reaches an average of 5,065 tons of fish annually which created invaluable job opportunities for the surrounding community. Lake Hayq is a freshwater lake located in South Wollo zone of Amhara region, Northern Ethiopia. It is one of the Highland Lakes of Ethiopia, located at an altitude of 2,030 meters above sea level. It receives water from many small seasonal streams

and one perennial river named Ankerka. The catchment area of the lake is 65 km². The lakes had a maximum depth of 88.2m and 81.44m recorded in 1941 and 2013, respectively (Seid, 2016). This lake is well known for its fishery resource for the community and nearby towns. It has a potential of an average 500 tons of fish production per year (Tesfaye and Wolff, 2014). The two study Lakes are illustrated in Fig. 1.

2.2. Sampling method and sample size determination

A simple random sampling approach was implemented from October 2017 to May 2018. The sample size for the postharvest loss interview process was estimated based on (Coe, 1996; Israel, 1992).

$$n = (N)/(1 + N(e^2))$$

where n, is the sample size, N is the population size, and e is the level of precision. Based on this formula, the total fishermen are estimated to be (N = 1000 by consulting agricultural offices operating in the two study lakes). From the total population, an estimated sample size of 290 fishers was calculated from all study sites with a confidence level of 95%, and a precision of 5%. Finite population correction formula further reduced the sample size; $n\prime = 1/(1/N + 1/n)$ (Coe, 1996; Israel, 1992). Where n, is the sample size, N is the population size and n' is the final sample size corrected. Based on this formula, the final sample size for the questionnaire was 75 individuals involved in fishing and marketing. However, to increases the
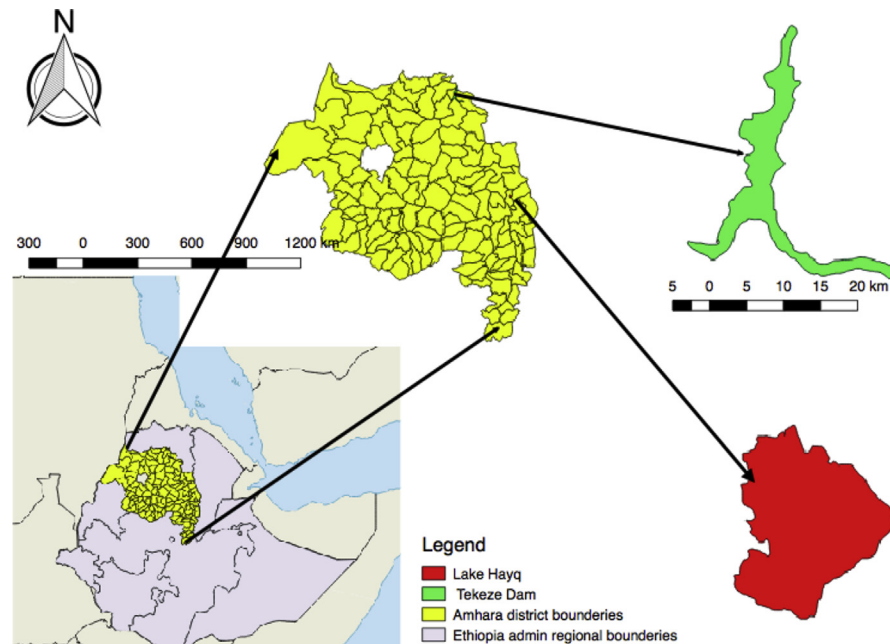
Fig. 1. A map that shows study sites.

precision of findings, the number of participants was raised to 140 individuals. The sample size was distributed proportionally between the two Lakes based on their production potential and number of individuals involved in fishing activities. Hence, 85 participants were interviewed from Tekeze dam while in Lake Hayq 55 individuals were involved in the interview process. The relatively higher number of participants from Tekeze was due to its higher production potential than Lake Hayq.

2.3. Post-harvest loss (PHL) assessment methods

Post-harvest loss assessment was carried out using qualitative and quantitative field assessment methods. Informal fish loss assessment method (IFLAM), load tracking (LT) and the questionnaire loss assessment method (QLAM) methods adapted from FAO were used to assess the causes and to estimate the amount of PHL of fish (Diei-Ouadi and Mgawe, 2011)).

2.3.1. Informal fish loss assessment method

Secondary data from district agricultural office reports about fish production and losses in the study areas were collected, and the estimate of PHL was calculated by the following formula (Formula 1).

$$monetary\ value\ of\ PHL = the\ amount\ of\ loss\ fish\ in\ tons * 1000 * price\ of\ fish \\ in\ kg * number\ of\ years$$

Formula 1: Formula used to estimate monetary value of PHL in the two study areas from secondary data.

2.3.2. Load tracking (LT)

Load tracking was used to measure weight loss at different stages along the distribution chain specifically at the Landing site and marketing site. A random fishing vessel was sampled for measurements, and at least 30% fish weight was measured in balance at the landing site and trader's store with nineteen replications. The physical loss was calculated by subtracting final weight from initial weight. Based on this, weight loss of different species of fish were measured at Tekeze dam for nineteen replications in forty-five days gap.

2.3.3. Questionnaire loss assessment method

A questionnaire was translated in Amharic and administered to fishers to generate information about loss and handling practices and to validate information generated by the informal fish loss assessment and load tracking methods. Types of loss,

reasons for the loss, frequency of loss, variables that affect loss, fishing gear type, seasonality, livelihood activities and other variables were recorded.

Based on FAO recommendations for study PHL, a matrix scoring was applied for every interviewee by having the list of probable, suspected causes to observe how much fishermen do agree or disagree with these causes (Table 3). These methods were found appropriate at Tekeze Dam only and applied there. The monetary value PHL incurred by individual fishermen was also estimated from the questionnaire based on Formula 1.

monetary value of the PHL = the amount of loss fish in kg incurred by fishermen on daily basis ∗ the average number of days fisherman works in a week ∗ price of fish in kg ∗ number of allowed fishing months

Formula 2: Formula used to estimate monetary value of PHL in the two study areas from the inter questionnaire loss assessment method.

2.4. Data management and analysis

All data generated in field and laboratory were entered, coded, and filtered in Microsoft Excel® version 2016 software. From the excel sheet, data were further exported and analyzed using Stata 14 (StataCorp. Stata, Statistical Software: Release 14. College Station, TX) for statistical handling purpose. Descriptive statistics (frequency tables and graphs) were used to visualize the findings, while the survey analysis function of Stata's GLM

$$Y = B_0 + b1X1 + b2X2 + b3X3 + b4X4 + b5X5 + b6X6 + b7X7 + b8X8 + b9X9 + e$$

where: Y = PHL incurred by fishermen on a daily basis, B_0 = Constant, X_1 = study Lake, X_2 = Boat type used X_3 Boat ownership, X_4 = Species of fish, X_5 = Preservation method used, X_6 = Distance to market (Km) X_7 = Maximum catch/day (Kg), X_8 = Minimum catch/day (Kg), X_9 = Fishing experience (years), and e = Error.

3. Results

3.1. Demographic characteristics of participants selected for the interview

A total of 140 participants were interviewed from the two study Lakes. Almost all of the participants were males with fishing experiences ranging from 1 to 30 years. Eighty-nine of the participants were married while the rest were single. The study lakes were bordered by seven districts. Particularly Lake Hayq was bordered by Tehuleder and Werebabo districts while Tekeze Dam was bordered by Abergelle, Ziqualla, Telemt, Sahala, and Tanqua Abergelle districts. Participants who harvest or

trade fish were included in this study. All demographic related information is depicted in (Table 1 and Figs. 2, 3, and 4)

## 3.2. Information on fisheries and related activities

Fishing activities in the two Lakes were studied to understand the causes for PHL and recommend actions needed to reduce postharvest loss and poor handling practices. Extensive data was generated on fishing-related activities to observe if these activities had relation to the loss that fishers incur on a daily basis. Most of the participants actively involved in fishing from October to March. Other data generated include how fishermen participate in fishing (private, cooperative, or share), type of equipment they possessed, type of net used, distance from fishing site to landing site/market, where they set gears, when they set gears, how much time they wait to allow nets to catch before hauling, how many days they are involved in fishing per week, season of excellent and poor marketing, season of high loss and other variables were generated (Table 2 and Figs. 5, 6, and 7).

3.2.1. Causes and extent of PHL associated with fisheries

Fishermen believed that high environmental temperature, absence (delayed) marketing, harvesting immature fish, the presence of predators, and flood are the significant

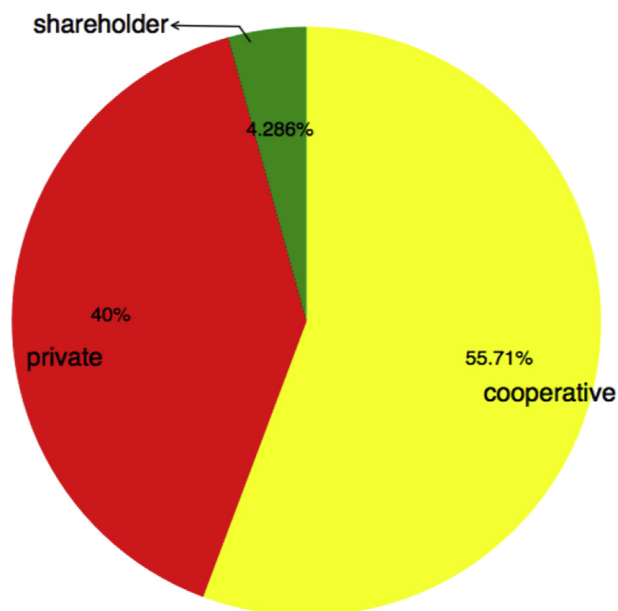**Table 1.** Demographic characteristics of participants.

Variables	Mean	Min	Max
Age	28.2 ± 7.7	15	55
Fishing experience	5 ± 3.5	1	30
Family size	3 ± 2	1	10
Annual income from fisheries (Ethiopian Birr)	22268 ± 109.75	5000	50000
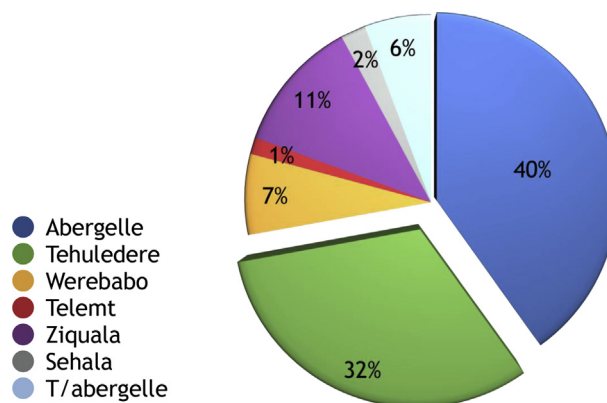
Fig. 2. Participant distribution across districts.
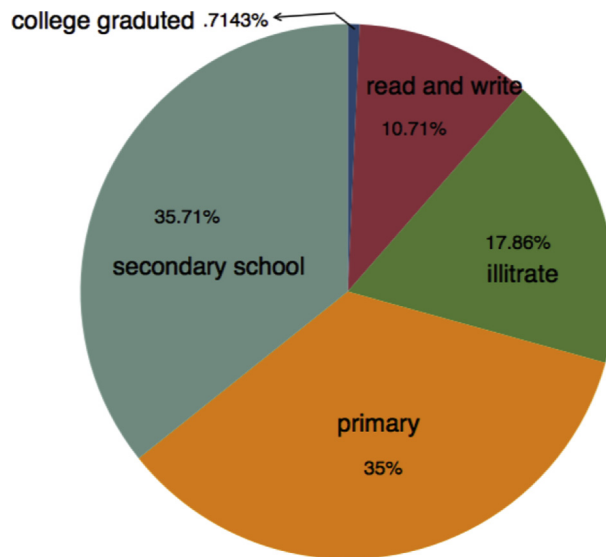
Fig. 3. Participant educational status.

**Fig. 4.** Participants membership.

reasons why they incur a loss in the two Lakes 80% of fishermen strongly agreed that long hours of setting gear before hauling causes high post-harvest quality loss, while 46% of fishermen from distant fishing grounds land large quantities of spoiled fish (Table 3).

Further, a GLM model consisting of different variables was developed. The analysis was done by using the daily loss of fish in kilograms claimed by fishermen as a response variable, and other relevant variables as predictors for loss. By using this

**Table 2.** Fishing activity variables generated by questionnaire.

Variables	Hayq			Tekeze			Both Lakes		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Distance to market (km)	2.0 ± 1.8	1	10	21.5 ± 7.4	1	70	13.9 ± 6.7	1	70
Number of gillnets owned	8.7 ± 5.2	1	30	5.8 ± 3.3	0	26	6.9 ± 4.4	0	30
Number of longlines owned	17.4 ± 17		90	32.2 ± 6.9	0	300	26.45 ± 3.6	0	300
wait time spent before marketing	0.6 ± 0.2	.5	2	3.4 ± 1.1	1	6	2.4 ± 1.6	.5	6
Fishing days in a week	5.8 ± 0.8	4	7	6.1 ± 1.1	3	7	6.0 ± 1.0	3	7
Wait time before hauling	6.2 ± 1.9	4	12	5.7 ± 1.3	2	9	8.25 ± 4.1	2	12
Maximum catch/person/day	10.4 ± 6.4	3	30	34.5 ± 19.8	5	105	25.1 ± 9.8	3	105
Minimum catch/person/day	2.8 + 1.8	1	8	1.1 + 0.5	1	4	1.8 + 1.5	1	8
Daily loss incurred in kg	1.04 + 0.9	0	6	6.8 + 5.6	0	25	4.5 + 1.3	0	25
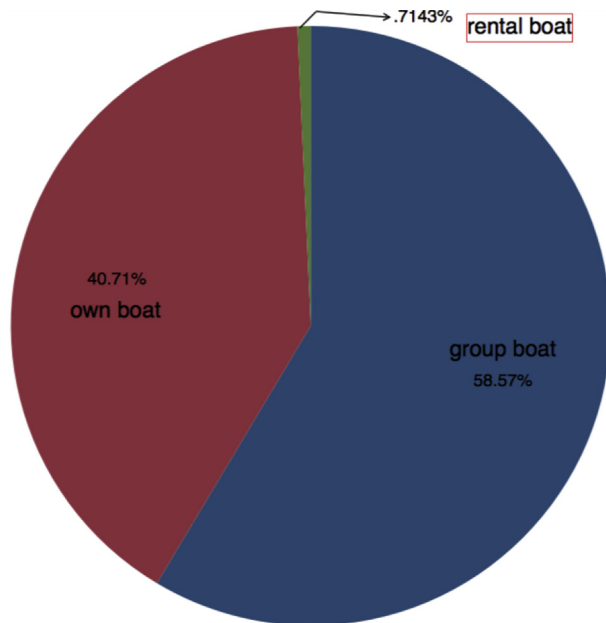
Fig. 5. Boat ownership of participants.

model, that some of the variables were found significantly associated with daily loss incurred. Continuous variables like distance travelled to reach the market, and maximum catch/day had a positive association with the amount of loss, while minimum catch/day and fishing experience had an inverse relation to the amount of loss. However, Fishing experience and minimum catch/day were inversely associated with an increased amount of PHL incurred by a fisherman. The other predictor variables found to have an association with fish loss were; species of fish harvested, type of boat used by fishermen, ownership of a boat, using preservation methods, and
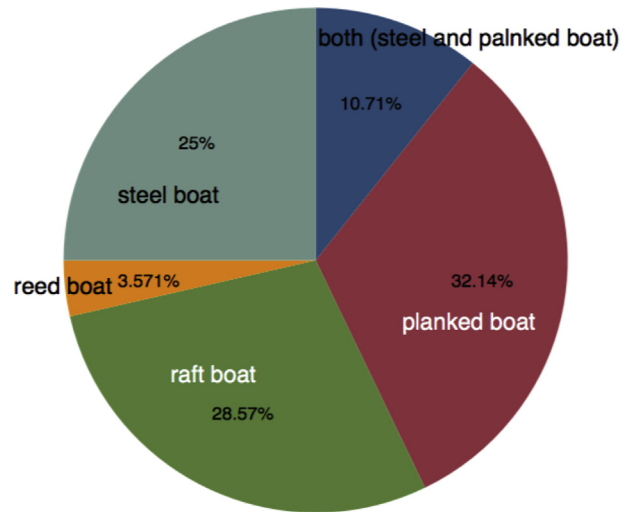
Fig. 6. Type of boat used by participants.
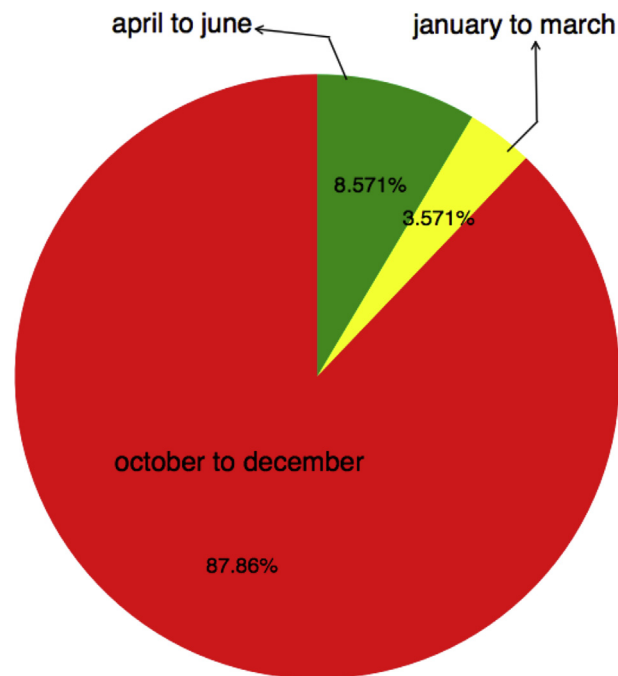
Fig. 7. Season of high loss.

study Lakes where participants were involved in fishing. A predictor model for PHL of fisheries in the study Lakes consisting of all significant variables is depicted in Table 4.

The other studied parameter about PHL was the monetary value of loss incurred by fishermen. It was calculated from the amount of fish loss incurred by fishermen on a daily basis. Interview from participants generated the amount of loss of fish in

Table 3. Causes of PHL based on Likert scale.

Variables	SA	A	NAND	D	SD
Long hours of setting gear before hauling causes high post-harvest quality loss	81.18	15.29	0	3.53	0
Fishers from distant fishing grounds land large quantities of spoiled fish	20.00	45.88	17.65	15.29	1.18
On average, two crates of fish are found spoiled on landing	4.71	21.18	45.88	27.06	1.18
High post-harvest fish loss occurs during the rainy season	3.53	42.35	22.35	17.65	14.12

SA-strongly agree A-agree, NAND-neither agree nor disagree, D-disagree, SD-strongly disagree.

Table 4. Multivariable GLM model that show an association between the amount daily loss and predictors.

Variables	Coefficients	P value	95% CI of B
Lake			
Hayq	Reference		
Tekeze	5.76631	0.01	4.5, 6.99
Boat type used			
Both (planked &steel)	Reference		
Planked boat	0.4	0.728	1.85, 2.65
Raft boat	−4.09	0.001	−6, −2.17
Steel boat	2.5	0.101	0.50, 5.65
Boat ownership			
Group boat	Reference		
Own boat	−4.6	0.001	−6, −3.2
Rental boat	13.6	0.001	12, 14.8
Species of fish			
Bagrus documak (Forsskål, 1775)	Reference		
Catfish spp.	−0.078	0.7	−0.6, −0.48
Labeobarbus spp.	4.97	0.01	3.8, 6.1
Tilapia (*Oreochromis niloticus*)	3.04	0.002	1.07, 5.0
Preservation method used			
No preservation	Reference		
Salting	−5.2	0.000	−6.7, −3.6
Sun drying	−2.34	0.016	−4.2, −0.43
Distance to market (Km)	1.18	0.042	0.06, 0.156
Maximum catch/day (Kg)	0.19	0.01	0.145, .23
Minimum catch/day (Kg)	−1.01	0.01	−1.4, −0.60
Fishing experience (years)	−0.17	0.01	−.27, −0.077
Constant	−3.89	0.054	−7.85, −0.062

kilograms. As indicated in Table 1, at Lake Hayq, a fisherman works for four days in a week on average and incur 1.04 kg loss of fish per day (see Table 2). Legal fishing season (a legal fishing season is a where fishers are allowed to fish in which the fish may not breed. In breeding season fishing is prohibited by law in the two lakes) of the year in that particular area ranges from October to April (7 months) while the rest is breeding season for the fish. In Hayq one kilogram of fish is sold for 120 Ethiopian Birr (ETB). With simple multiplication, (1.04 kg*120 birr*7 month*16 days/month) the estimated total loss per fisherman in that particular Lake is found to be 13,977.6 ETB per year (equivalent to 500 USD/year/individual). Based on similar calculations for Tekeze Dam, a fisherman works actively for six days in a week and sell fish 90 ETB per kg. with similar calculations, (6.8 kg loss/day *90 birr*7 month*24 days/month). The total monetary loss per individual in the Tekeze dam was found to be 102,816 ETB per year (equivalent to 3672 USD/year/individual).

3.2.2. PHL estimation based on secondary data

Based on secondary data generated from the district agricultural office, the total annual fish production and loss are depicted (Table 5).

The amount of loss in terms of money was estimated with a simple calculation. One kilogram of fish has been sold 60 and 80 ETB (average fish price of the production years) at Tekeze and Hayq respectively for the last six years. Total monetary loss was calculated by the amount of production in kg*price of fish/kg. for Tekeze the monetary loss (108.9 **ton*1000*60** = 6,534,000). While for lake Hayq, the monetary loss was estimated as (55.5 **ton*1000*80 birr** = 4,400,000 Ethiopian Birr was lost at Tekeze dam and Lake Hayq respectively which is equivalent to 397,600 USD in the two Lakes.

Table 5. Total Fish production and loss between 2012 to 2018.

Year (EC)	Hayq		Tekeze		Total	
	Production (ton)	Loss (ton)	Production (ton)	loss	Production (ton)	Loss (ton)
2012	341	15	NA	NA	NA	NA
2013	413	8	NA	NA	NA	NA
2014	292	12	NA	NA	NA	NA
2015	213	6	813.1	38.7	1026.1	44.7
2016	381.5	5	1570.53	40.9	1952.03	45.9
2017	120	4.5	3661.84	24.6	3781.84	29.1
2018*	46.2	5	189.52	4.7	235.72	9.7
Total	**1806**	**55.5**	**6234.99**	**108.9**	**8040.99**	**164.4**

NA, data not available, * data available till February 2018 EC

3.2.3. PHL estimation by load tracking

The amount of loss was generated by subtracting final weight in measured in store from initial weight measured at landing sites (Table 6). Since the measurements included measuring before and after filleting of fish, it was not possible to estimate the monetary value of the loss.

4. Discussion

Almost all of the participants included for the interview process from the two water bodies were males. This condition may not be surprising because men in Ethiopia dominated most of the agricultural practices and fishing activities (Assefa and Bahiru, 2018). Fisheries sector in the study areas has been contributing a massive role in fighting poverty and malnutrition. Recently the government gave attention to fisheries cooperative establishment to lower the unemployment level, especially in the youth group. Rents with low interest and small grants have been provided by the government to the communities so that they can work together and generate incomes from the sector.

According to the respondents, fish is surplus from October to March at both Lakes. The reason for fish abundance was the fishing prohibition from May to September as a breeding season which makes the next seasons to be abundant regarding production. Participants said that months from October to December are also seasons of high loss because of increased production. In these month absences of a market is high and the price of fish can be much lower than in other seasons. This condition is recognized as market force loss which is one of the challenges of the fisheries sector (Tesfay and Teferi, 2017). This situation was much severe at Tekeze Dam than Lake Hayq because; Tekeze fishers sell their only to wholesalers who deliver fish to Addis Ababa or Mekelle cities. If wholesalers fail to receive producers in every single day, fishers may not have any option of selling their harvest around Tekeze. There was not a single restaurant and local retail markets in Abergelle as well as Sekota town. During high production months of October to December, producers incur a massive loss on a daily basis. fishermen threw their harvest in the wild if a

Table 6. Fish loss generated by load tracking.

Species of fish	Initial weight (Kg)	Final weight (Kg)	Loss (difference) (Kg)
Oreochromis niloticus	60.01	16.96	43.05
Bagrus documac	145.34	89.3	56.04
Catfish species	156.85	89.7	67.15
Labeobarbus species	9.95	4.215	5.735
Total loss	**372.15**	**200.175**	**171.975**

whole day awaited buyer cannot receive all the product. Fish loss is much lower and expensive regarding price in Ethiopian orthodox church fasting seasons (January to March). In these months fish fetches a reasonable price, and they may not encounter market force loss due to 1) fish is not surplus in these months because of exploitation in previous high production season 2) during the fasting season other animal products are prohibited and fish can be served in some restaurants so that traders actively buy fish and take it to Addis Ababa and Mekele cities.

Findings of this study in line with the findings of (Tesfay and Teferi, 2017) conducted in Ethiopia in identifying causes of PHL (high environmental temperature, harvesting immature fish, the presence of predators, loss of fish in the Lake with the net, high flooding, and delay before marketing). These factors were also reported elsewhere as essential causes of PHL (Adelaja et al., 2018; Bengwe and Kristófersson, 2012; Olusegun and Mathew, 2016; Ward, 1996). All these causes (high environmental temperature, harvesting immature fish, the presence of predators, loss of fish in the Lake with the net, high flooding, and delay before marketing) can lead to a physical loss of product which further leads to a penalized market value (Ahmed, 2008). The high environmental temperature was noticed in Tekeze during the study period. As the temperature reaches more than 35 °C (mid-day), fishers reach landing site from sites where they set nets. By that time, their product could have been lost due to mid-day high temperature and the distance travelled to reach landing site (market). Harvesting immature fish was also the other reason for higher PHL. In the study areas, fishermen mostly use a monofilament net that catches mature and immature fish indiscriminately. If an immature fish is captured that may fail to be marketed due to its small size, it is going to spoil in the process because fishermen may throw it in landing site or the water body. Hence, harvesting immature fish and throwing it away can increase postharvest loss as well as overexploitation of the resources of the Lakes. This condition was much higher in Lake Hayq than Tekeze Dam. Predators like alligators and crocodiles at Tekeze and, Pelicans and other birds in Lake Hayq, were also the other reasons listed out by interviewees as causes for fish loss. These animals were found in abundance in the study areas. Reports indicate that predator animals and insect infestation are among the critical factors that can increases PHL in the sector (Ahmed, 2008; Akande and Diei-Ouadi, 2010).

Long hours of setting gear before hauling and distance to landing sites are essential causes of loss at Tekeze Dam. The average time for setting gear by fishermen was 6 hrs. Participants believed that, if a fisherman forgot to check the net in shortest possible time, it could result in the death of fish and further spoilage during transportation. Which is why participants agreed to the matrix of long hours of setting gears can result in increased fish PHL. Fishers from far districts travel a maximum of 70 km by boat to reach marketing site (landing site). During this time fish may undergo spoilage due to environmental and spoilage bacteria. The other matrix result that had

a substantial agreement between participants was flooding (rainy season). Since Te-keze Dam has many tributaries, if there is unexpected rain in the highland areas, the flood can reach the Dam and reduce the shelf life of the fish harvested by contaminating the skin, gills, and GIT of fish with environmental bacteria. Even if fishermen did not understand the reason behind, they claimed that if there is a flood fish undergo spoilage in a short time. However different kinds of literature stated that fish quality is in direct relation to water quality (Boyd, 2017; Zhao et al., 2018).

The GLM model indicated that some variables had a significant association with the amount PHL. The reason for the positive association between the amount of loss and distance travelled to reach the market, and maximum catch/day can be travelling a far distance to sell the product, and catching plenty of fish where there are not enough buyers in the market may cause higher loss. However, Fishing experience and minimum catch/day were inversely associated with an increased amount of PHL incurred by a fisherman. This can be due to the fact that if a fisherman is experienced enough in fishing, he might be able to manage to reduce loss, and also if a man catches few kilograms of fish, he may not incur loss because either he manages it well and sell to the wholesaler, or he might take it home to consume with family. As observed from the model, if a fisherman had his boat than a group boat, he may manage to reduce PHL. This may be true since having own property by fishermen may be well managed to reduce loss. Besides, if a fisherman uses some preservative methods like sun drying, he can manage to reduce loss significantly. Studies showed that preservative methods like sun-drying, salting, and smoking are known to reduce PHL in developing countries (Bengwe and Kristófersson, 2012). Regarding species, mostly harvested as claimed by fishermen, they may incur a higher loss in Tilapia (*Oreochromis niloticus*) and *Labeobarbus spp* than *Bagrus documak.* The reason for higher loss in Tilapia (*Oreochromis niloticus*) can be its abundance in the two Lakes than any other species which may increase the amount of loss relatively than other scarce species. The amount of PHL was found to be higher at Tekeze Dam than Lake Hayq. The reason for this difference can be due to many factors. Some of the most important reason can be 1) traveling a long distance (a maximum of 70 km) to reach the market in Tekeze, and 2) the production volume of Lake Hayq is gradually decreasing time to time (Vijverberg et al., 2012). The decreased production forced fishermen and consumers to utilize the catch effectively without incurring much loss. During the interview process participants from Hayq replayed that "*what amount I am going to lose from this? We produce few kgs of fish per day here, even not enough for resorts found around the Lake*". 3) Lake Hayq fishermen do have many options for selling their product, unlike Tekeze Dam fishermen. In lake Hayq, many restaurants serve fish in nearby cities of Hayq, Dessie, and Kombolcha. This chance of selling directly to restaurants is not available in Tekeze Dam. These reasons might have contributed to a much higher rate of loss in Tekeze than Lake Hayq.

Regarding the monetary value of fish loss in the two study areas, Secondary data utilized from agricultural offices indicated that the loss of fish in the sector is huge. The country loses a total of 164.4 ton of fish from the two Lakes in the last 4−6 years. The loss of resources regarding money was found to be 6,534,000 and 4,400,000 Ethiopian birrs at Tekeze Dam and Hayq respectively for the last 4−6 years which is equivalent to 397,600 USD. A study conducted in Lake Tekeze (different landing site from this study was taken), and in Hashenge Lake estimated a total monetary loss of 4,822,560 ETB (Tesfay and Teferi, 2017), which is considerably lower than estimated by this study. This lower estimation can be due to 1) the price of fish increased by 100% between the two studies, 2) the year gap between the two studies in which this study included fish loss recorded after their measurement, 3) this study included the production and loss data of Abergele, Ziquala, and Sahala districts (Amhara region). The previous study estimated loss from Tanqua Abergelle district (Tigray region) only. Another study conducted in Amerti and Fichawa reservoirs, Ethiopia estimated a relatively lower estimate than in this study as well. They reported a loss of annual 6.81 tons of fish (Teklu, 2014). This difference can be due to these reservoirs have considerably lower fish production potential than Tekeze and Hayq.

The monetary value of fish loss generated by interview indicated that a total of 13,977.6 and 102,816 ETB per year/per fishermen at Lake Hayk and Tekeze Dam had been lost respectively. This calculation (from the interview) was somehow in line with calculations from secondary data. The loss estimated from the interview indicated that there is still a huge loss in terms of money from the two study areas. This calculation is an annual loss incurred by a single legally registered fisherman. As the number of fishermen may not be figured out clearly because there are illegal fishermen as well, who sell their product in secret, estimating the exact annual loss may not be possible. The number of illegal fishermen fluctuates from time to time depending on the security level implemented by local militia. However, this result is a clear indication that there is a significant amount of resource being lost in these areas.

5. Conclusions

High environmental temperature, harvesting immature fish, the presence of predators, flooding, predators and delay before marketing were the most determining causes of PHL in the study areas. The estimated monetary loss was found to be 10,934,000 ETB (equivalent to 397,600 USD) for the last 4−6 years from both lakes. This much loss may need intervention by stakeholders to overcome such a huge economic loss. The findings of this study can be used as a basis for planning of intervention measures to reduce resource loss in these and other Lakes of the country. Fishermen need developmental interventions by responsible organizations.

Provision of preservation items like freezers, generators, boats, net and on job training about proper fish handling practices may play a tremendous role in decreasing loss in the two study Lakes.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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