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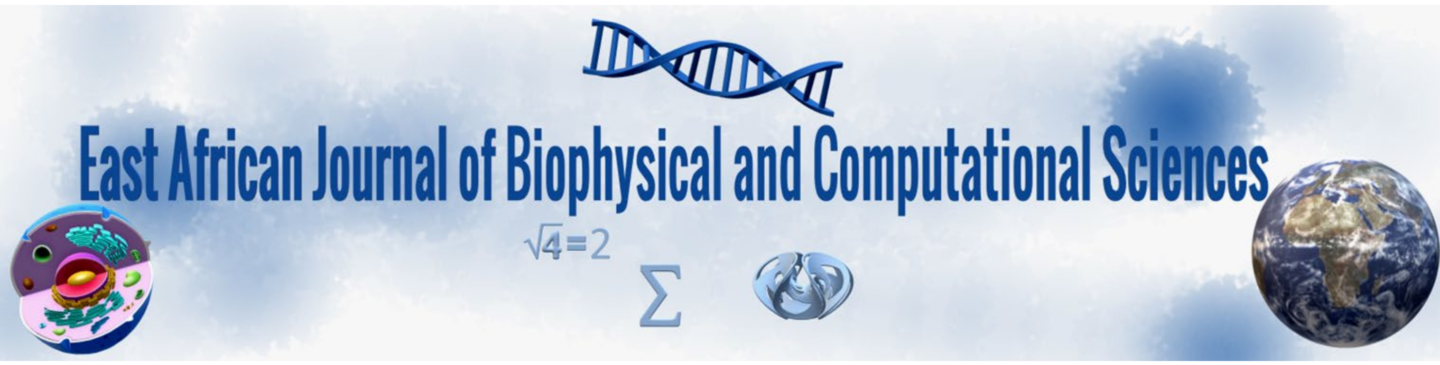

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Biodiversity conservation and threat reduction in Kibale and Queen Elizabeth conservation areas, Uganda

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KEYWORDS:

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Research article

ABSTRACT

This paper examines threats affecting the wildlife conservation areas, threat reduction and adaptive management strategies that enhance biodiversity conservation. The research was conducted through a survey, and data was collected from August 2018 to April 2019 in Kibale and Queen Elizabeth Conservation Areas using literature review, threat reduction assessment technique, Key Informant Interviews and Focused Group Discussions and semi-structured questionnaires. The data was analysed using Geographical Information System software ESRI ArcGIS version 10.31, threat reduction assessment tool, Pearson Chi square test, Spearman's rho correlation coefficient, Paired Samples t-Test, and one-way Analysis of Variables. The study established that staff education level and experience in conservation work influences biodiversity conservation. The conservation areas are threatened by habitat transition/changes, wild fires, human-wildlife conflicts, armed poaching and illegal wildlife trade/trafficking in game meat and game products, increasing human population pressure, and boundary encroachment. Despite these threats, there was a general increase in large mammal population over the past decades, which collaborates well with the threat reduction assessment indices. Both conservation areas had an ecological integrity rating average score of "yellow" indicating significant "concern" and therefore "dissatisfactory". The two conservation areas are majorly threatened by anthropogenic threats, natural threats, and administrative constraints. The wildlife agency should integrate ecosystem health into the conservation agenda. The agency should also strengthen adaptive management, law enforcement, and collaboration with local communities and other stakeholders to reduce on the threats. Finally, further research should focus on ecosystem health, and also the impact of tourism infrastructural development on biodiversity conservation.

INTRODUCTION

Protected areas harbour a particularly rich and unique biodiversity (Gibson et al.,2011; Tranquilli et al., 2014). However, their existence is challenged by many interrelated anthropogenic activities that have intensified over recent decades (Laurance, 1999; Sodhi et al., 2007; Wittemyer et al., 2008; Tranquilli et al., 2014). Increased human population growth

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has promoted the rapid expansion of threats to wildlife, habitat destruction through agriculture and unsustainable hunting of wildlife. Biodiversity is the wealth of all life forms found on earth and encompasses all species of plants, animals, microorganisms, the ecosystems and ecological processes. Moral justification and value to human existence are two major reasons for conserving biodiversity (Christ et al., 2003). However, renewable natural resources are being utilized by humans at a rate exceeding their natural abilities to renew themselves (Christ et al., 2003). Human encroachment into natural ecosystems is increasing drastically throughout the world. Forests are being exploited and cleared, farmlands have increased in extent, demand for grazing areas is on the rise and unregulated harvesting of the wild resources is becoming uncontrollable. As human activities exert pressure on the global environment, biological diversity declines, habitats are transformed and the population of some species dwindles to the point of extinction (Whitmore and Sayer, 1992). Since man is constantly at variance with nature, the ever increasing human population coupled with technological development place stress on the environment and the world's natural resources hence the unprecedented rate of biodiversity disappearance.

Threats to biodiversity in Africa have led to the creation of numerous protected areas (PAs), which are intended to conserve both fauna and flora, whilst benefitting neighbouring human communities. Nevertheless, human populations throughout Africa have increased the amount of pressure being exerted on PAs. Thus, despite their legal protected status, PAs face significant threats(Tranquilli et al., 2014). The most concerns are overexploitation of natural resources, habitat loss, fragmentation and isolation (Wittemyer, 2008; Laurance, 2012). These factors impact severely on key species and especially taxa with large body sizes, slow reproductive rates, and little behavioural adaptability (DiMarco, 2014).

Protected areas (PAs) are a cornerstone of biodiversity conservation efforts, as they provide various species with safe havens (Radeloff et al., 2010). Protected areas now cover more than 14.7% of the terrestrial land surface (UNEP-WCMC, IUCN, 2016). Recent syntheses suggest that PAs are performing better than the broader landscape (Barnes et al., 2016; Gray et al., 2016), although numerous studies suggest that biodiversity continues to decline within many PAs (Craigie et al., 2010; Laurance et al., 2012; Geldmann et al., 2013). A principal objective of PAs is to conserve nature by eliminating or reducing human pressures and threats operating within their boundaries. In addition to preserving biodiversity, PAs should maintain natural processes and promote survival of species by excluding threats (Margules & Pressey, 2000). To achieve these goals, we must understand what the main threats are, where the potential threats occur, and where high-risk areas are distributed. Identifying these threats is therefore crucial for conservation managers to take effective measures to mitigate some of the proximate threats to PAs (Wilson et al., 2005).

Knowledge of the occurrence and severity of threats to PAs has largely been informed by remote sensing data (Geldmann et al., 2014), modeling (Hole et al., 2009), as well as questionnaire surveys with an emphasis on tropical regions (Bruner et al., 2001; Leverington et al., 2010; Laurance et al., 2012). Freely available satellite data offer global and standardized metrics form measuring those threats to PAs that can be observed remotely, such as deforestation (Joppa and Pfaff, 2011) and fires (Nelson and Chomitz, 2011). However, many other threats, including some of the most frequently reported threats to species, according to the International Union for Conservation of Nature (IUCN) Red List (e.g., overexploitation of species, invasive alien species, pollution, climate change), cannot be measured from space (Joppa et al., 2016) and require field-collected data (Mwangi et al., 2010).

In Uganda, however, little research has been done on the level of threats affecting biodiversity, their consequent impacts in protecting ecological integrity, and therefore, little documentation on the recommendations to mitigate biodiversity threats. Therefore, the main aim of this study was to document the threats affecting the protected areas and propose adaptive management strategies to biodiversity conservation. The specific objectives were to (i) identify threats to biodiversity in the case study conservation areas, (ii) generate the threat reduction assessment (TRA) index for each PA; and (iii) identify management measures employed by the parks that enhance effectiveness and efficiency in addressing threats.

Overall, this study presents tools for PA managers to make effective conservation and restoration decisions and consequently an important influence on global biodiversity conservation.

MATERIALS AND METHODS

Selection of the conservation areas for the study

This study was carried out in the national parks and wildlife reserves within Kibale and Queen Elizabeth Conservation Areas because their General Management Plans only highlight the different management challenges that affect the integrity of the protected areas without specifying the threat levels (UWA, 2012, 2015), and also for logistical reasons. Based on knowledge of national parks and wildlife reserves in Uganda, purposive sampling (Babbie and Benaquisto, 2002) was used to select the two conservation areas. Specifically, the national parks and wildlife reserves included in this study were: Kibale National Park (795 km^2), Semuliki National Park (220 km^2), Toro-Semliki Wildlife Reserve (542 km^2) and Katonga Wildlife Reserve (207 km^2) in Kibale Conservation Area; and Queen Elizabeth National Park (1978 km^2), Rwenzori National Park (995 $km^{2.}$), Kyambura Wildlife Reserve (157 km^2) and Kigezi Wildlife Reserve (330 km^2) in Queen Elizabeth Conservation Area (Fig.1)

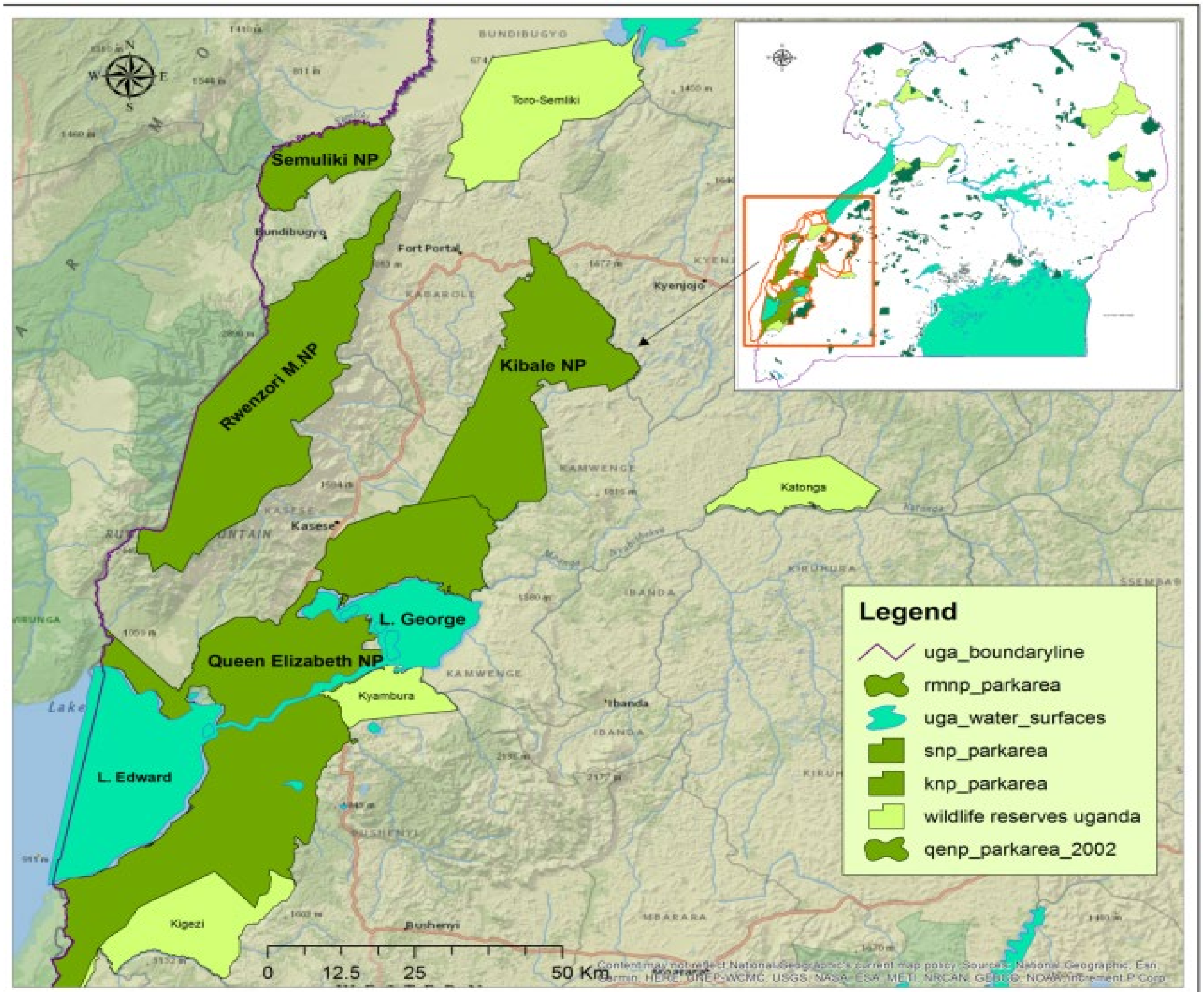

Fig 1: Map showing Kibale and Queen Elizabeth Conservation Areas and location of study sites.

The sample size and sampling technique

The sample size of the respondents used during the study was determined using the method adopted from Krejcie and Morgan (1970) The study adopted stratified and purposive sampling technique to collect focused information. A total of 287 questionnaires were administered, and these were segregated as 208 individuals from households in the communities adjacent the case study wildlife protected areas, 53 to park staff, 4 to ecological experts, 16 to representatives of local authorities, 2 to Uganda Wildlife Authority headquarters, 2 to Wildlife Conservation Society-Uganda, and 2 to the Ministry of Tourism, Wildlife and Antiquities.

Data collection

The data and information used to determine the threats to conservation and how they were being addressed was collected from August 2018 to April 2019. Permission to conduct the study was obtained from Uganda Wildlife Authority prior to the start of the survey. In-depth interviews with 53 randomly selected resident park staff in the four national parks and four wildlife reserves of Kibale and Queen Elizabeth Conservation Areas was carried out. Eight focused group discussions (FGDs), one per protected area, were made to collect data on the existing threats and identify management options to address them. Each FGD had 5 to 8 park staff. Four ecological experts who had conducted and or supervised various studies in the case study protected areas were interviewed to get expert judgment on the ecological integrity indicators. Key informant interviews (KII) with two representatives (district political head and district environment/natural resources head) from each of the eight selected district local governments neighboring the parks and wildlife reserves; and six national level representatives mainly from Uganda Wildlife Authority, Wildlife Conservation Society-Uganda, and Ministry of Tourism, Wildlife and Antiquities to gather more information. Semi-structured questionnaire were administered to 208 randomly selected community respondents living adjacent the parks and wildlife reserves. In addition, literature review to identify relevant existing information on the national parks and wildlife reserves pertaining wildlife conservation was also done. This data collection was guided by semi structured questionnaire that generated both qualitative and quantitative responses. Both primary and secondary data were collected. Specifically, data were obtained directly from the park staff, and existing literature including park reports, general management plans and annual operation plans, annual reports, field monitoring reports and routine reports. The threats to habitat integrity, quality and ecosystem functioning were identified.

Data analysis

Staff at each park and wildlife reserve headquarters were interviewed and GPS points were collected using Garmin eTrex GPS. These collected points in form of latitudes and longitudes were downloaded, entered in Ms-excel, converted to decimal degrees and exported to Geographical Information System (GIS) software ESRI ArcGIS version 10.31 for map production. Responses from the park staff were analyzed using descriptive statistics, and inferential statistics as in the Statistical Package for the Social Sciences (SPSS) Version 22. The statistical tests used in analysis were Pearson Chi square test, Spearman's rho correlation coefficient (r), Paired Samples t Test, Friedman test statistic, and Kruskal-Wallis Analysis of Variance (ANOVA). In addition, the TRA approach by Margoluis and Salafsky (1998) was adopted to assess the main types of threats affecting the PAs, their occurrence, their impact, and their reduction levels. Following Salafsky et al. (2008), threats are defined as any human activity or processes that caused destruction, degradation, and/or impairment of biodiversity targets. This approach based on three key assumptions: a) all biodiversity destructions are human-induced; b) all threats to biodiversity at a given site can be identified and c) changes in all threats can be measured or estimated (Margoluis and Salafsky, 1998). The TRA method identifies threats, ranks them based on the criteria and assesses the progress in reducing them (Rome, 1999). The TRA approach followed the procedural approach developed by IUCN (1998), Margoluis and Salafsky (1999) that involved:

a) Defining the protected area and listing all direct threats present at the site;
b) Ranking each threat based on three criteria: area, intensity and urgency (area refers to the percentage of the habitats in the site; intensity refers to the impact or severity of destruction caused by the threat; and urgency refers to the immediacy of the threat. Out of the total threats, the highest ranked threat for each criterion receives the highest score, and lowest ranked score receives the lowest score;
c) Adding up the scores across all the three criteria for total ranking;
d) Determining the degree to which each threat has been met;
e) Calculating the raw score for each threat and multiplying the total ranking by the percentage calculated to get the raw score for each threat; and
f) Calculating the final threat reduction index score by adding up the raw scores for all threats, dividing by the sum of the total rankings, and multiplying by 100 to get the TRA index as a percentage.

This TRA approach is much simpler and cost effective, as it measures changes in the broader human activities that threaten the integrity of the resource, and then uses that information to draw inferences on the state of the resource itself.

sampling method. By rule of thumb where there is no information for an area it is possible to take 50% of expected prevalence. Using 5% degree of absolute precision, 384 animals need to be sampled but, 400 animals were sampled.

RESULTS

The study documented the threats to biodiversity in the case study national parks and wildlife reserves. Both primary and secondary threats were identified (Table 2), and their threat reduction percentages and indices calculated (Table 3). The management strategies employed to reduce on the identified threats to enhance wildlife conservation were also documented (Table 4).

Demographic characteristics of the respondents

Park staff responses

The park staff respondents were segregated as 20.8% females and 79.2% males. The Chi square test result was statistically significant (χ^2 (1, N = 53) = 18.132, p =0.000, Cramer's Value=0.445) and the high Cramer's Value indicates a strong effect of gender in conservation. Further analysis using the paired samples t test revealed statistically significant results with t(52) = 8.616, p = 0.000, α = 0.05 (Table 1) indicating that gender plays a vital role in conservation. The staff had varying education levels with majority (43.4%) having a diploma, and 35.8% a college degree in biological science and other related discipline. (Table 1) Analysis by the Pearson Chi-square test revealed statistically significant result that education level had an effect on biodiversity conservation (χ^2 (21, N = 53) = 22.222, p =0.000, Cramer's Value=0.374) and the high Cramer's value indicates a very strong effect. Further analysis using a paired t test revealed statistically significant results t(52) = 5.654, p = 0.000, α = 0.05 (Table 1) indicating that education had a strong correlation with biodiversity conservation. On work experience demographic, 30.2% had between 11 to 15 years, and another 30.2 had over 16 years work experience in wildlife management and biodiversity conservation (Table 1), and the Pearson Chi-square test revealed statistically significant result that working experience had an effect on biodiversity conservation (χ^2 (196, *N* = 53) = 214.774, *p* = 0.000, Cramer's Value = 0.490). The high Cramer's value indicates a very strong effect. Further analysis using the paired samples *t* test revealed statistically significant results t(52) = 3.817, p = 0.000, α = 0.05. (Table 1) Further analysis on the relationship between length of work experience and level of understanding mandate of PAs using Spearman's rho correlation coefficient (r) revealed statistically significance result (Spearman's rho, r= 0.780, p= 0.000, N=53).

Table- 1: Socio-demographic characteristics of park staff

Variable		Number (N)	Percentage (%)	Chi-square test (χ^2)	t test statistic
Gender	Male	42	79.2	*χ^2 (1, N = 53) = 18.132, p = 0.000, Cramer's Value= 0.445*	*t(52) = 8.616, p = 0.000, α = 0.05*
	Female	11	20.8		
Level of education	Secondary	10	18.9	*χ^2 (21, N = 53) = 22.222, p = 0.000, Cramer's Value= 0.374*	*t(52) = 5.654, p = 0.000, α = 0.05*
	Certificate	1	1.9		
	Diploma	23	43.4		
	Degree	19	35.8		
Years in service	<5 years	8	15.1	*χ^2 (196, N = 53) = 214.774, p = 0.000, Cramer's Value= 0.490*	*t(52) = 3.817, p = 0.000, α = 0.05*
	[5-10) years	13	24.5		
	[10-15) years	16	30.2		
	[15-20] years	10	18.9		
	>20	6	11.3		

Community responses

Responses from the local communities adjacent the wildlife protected areas also revealed that that gender is an important factor in appreciating threats to the wildlife resources and participating in their reduction as revealed by significant χ^2=137.263, d.f=3, p=0.000, N=205, Cramer's Value=0.350 and *t(145) = 0.311, p = 0.265, α = 0.001*. Other demographic factors mainly age [(χ^2=137.263, d.f=3, p=0.000, N=205, Cramer's Value=0.350; and *t(145) =0 .311, p = 0.265, α = 0.001)]*, education level [χ^2=88.051, d.f=4, p=0.000, N=195, Cramer's Value=0.159 and *t(137) = 1.603, p = 0.001, α = 0.001]*, length of residence [χ^2=174.884, d.f=55, p=0.000, N=190, Cramer's Value=0.617 and *t(139) = 0.545, p = 0.019, α = 0.001*] and land holding [χ^2=79.258, d.f=2, p=0.000, N=194, and *t(139) = 3.940, p = 0.000, α = 0.001]* had an influence on community participation in wildlife conservation aimed to reduce threats to wildlife resources (Table 2).

Table- 2: Socio-demographic characteristics of community respondents

Variable		Number (N)	Percentage (%)	Chi-square test (χ^2)	t test statistic
Gender	Male	139	66.8	*χ^2=23.558, d.f=1, p=.000, N=208, Cramer's Value=.231*	*t(148) = 2.063, p = 0.000, α = 0.001*
	Female	69	33.2		
Age (in years)	18-31	56	27.3	*χ^2=137.263, d.f=3, p= 0.000, N=205, Cramer's Value = 0.350*	*t(145) = 0.311, p = 0.265, α = 0.001*
	32-45	118	57.6		
	46-60	15	7.3		
	61+ years	16	7.8		
Level of education	Primary	82	42.1	*χ^2=88.051, d.f=4, p=0.000, N=195, Cramer's Value= 0.159*	*t(137) = 1.603, p = 0.001, α = 0.001*
	Secondary	57	29.2		
	Certificate	21	10.8		
	Diploma	20	10.3		
	Degree	15	7.7		
Land holding	Owns land	159	82.0	*χ^2=79.258, d.f=2, p=0.000, N=194*	*t(139) = 3.940, p = 0.000, α = 0.001*
	Landless	35	18.0		
Owned Acreage (in hectare)	<1	7	5.3	*χ^2=162.091, d.f=1, p=0.000, N=132, Cramer's Value=0.249*	*t(93) = 3.060, p = 0.000, α = 0.001*
	1-3	84	63.6		
	3-5	13	9.8		
	5-10	21	15.9		
	>10	7	5.3		
Length of residence	1-3 years	8	4.2	*χ^2=174.884, d.f=55, p=0.000, N=190, Cramer's Value=0.617*	*t(139) = 0.545, p = 0.019, α = 0.001*
	4-6 years	13	6.8		
	7-9 years	9	4.7		
	≥10 years	160	84.2		
Occupation of respondents	Formal employment	15	10.2	*χ^2=69.023, d.f=4, p=0.000, N=148, Cramer's Value=0.598*	*t(89) = 1.705, p = 0.092, α =0 .05*
	Business	23	15.5		
	Religious leaders	2	1.4		
	Peasant farmers	85	57.4		
	Fisher folk	23	15.5		
Distance of household from the park boundary	<5km	130	75.1	*χ^2=190.465, d.f=2, p=0.029, N=173, Cramer's Value= 0.201*	*t(145) = 3.010, p = 0.003, α = 0.001*
	5-10km	32	18.5		
	>10km	11	6.4		

Threats to biodiversity conservation

Across the landscape, the study found that all the case study national parks and wildlife reserves experience nearly similar threats which affect conservation of biological diversity therein. Out of a total of 13 threats identified, six were primary and common threats to all and these were: i) increasing human population pressure leading to illegal activities/resource off-take, ii) poaching and illegal wildlife trade/trafficking in game meat and of recent in Ivory, iii) habitat transition/changes due to invasive alien species, iv) human-wildlife conflicts arising from wildlife attacks to humans and livestock, and destroying crops, v) wild fires, and vi) boundary encroachment through agricultural development and urbanization (Table 3).

Table- 3: Prevailing Threats within the Conservation Areas

	Threats	**Conservation Area**							
		Kibale				Queen Elizabeth			
		Kibale	Semuliki	Toro-Semliki	Katonga	Queen Elizabeth	Rwenzori Mountains	Kyambura	Kigezi
1	Human population pressure	1	1	1	1	1	1	1	1
2	Poaching and illegal wildlife trade	1	1	1	1	1	1	1	1
3	Habitat transition/changes	1	1	1	1	1	1	1	1
4	Human-wildlife conflicts	1	1	1	1	1	1	1	1
5	Wild fires	1	1	1	1	1	1	1	1
6	Boundary encroachment	1	1	1	1	1	1	1	1
7	Zoonotic and vector-borne diseases	1	1	0	1	1	0	1	1
8	Infrastructure development	1	1	0	0	1	0	0	0
9	Road kills	1	1	0	0	1	0	0	0
10	Trans-boundary issues	0	1	0	0	1	0	0	1
11	Poor waste management	1	0	0	0	0	1	0	0
12	Variation in water quality and quantity	0	0	0	0	1	0	0	0
13	Negative impacts of climate change	0	1	0	0	0	1	0	0

1=present; 0=absent

The rest of the threats were subjected to One-Way ANOVA to compare their means. The results revealed sufficient evidence to conclude that the threats were different as the test statistic was significant for zoonotic diseases and vector-borne diseases ($F_{2,\ 50}$=21.708, p=0.001), infrastructural developments ($F_{2,\ 50}$=10.201, p=0.001), transboundary issues ($F_{2,\ 50}$=0.677, p=0.001), and negative impacts of climate change ($F_{2,\ 50}$=10.362, p=0.001) and hence categorized as secondary threats. However, the test statistics results were not significant for road kills ($F_{2,\ 50}$=2.722, p>0.001), and poor waste management ($F_{2,\ 50}$=1.802, p>0.001) hence do not pose serious threats to wildlife protected areas.

Further, administrative constraints pose a threat to biodiversity conservation. Analysis using the one way ANOVA test revealed that inadequate funding ($F_{7,\ 45}$=5.095, p=0.000), insufficient incentives ($F_{7,\ 45}$=0.35, p=0.000), and inadequate patrol equipment ($F_{7,\ 45}$ =0.328, p=0.001) were statistically significant constraints to biodiversity conservation. Other constraints not statistically significant were poor staff housing ($F_{7,\ 45}$ =0.35, p=0.926), and weak support from neighboring communities ($F_{7, 45}$ =0.35, p=0.937).

Threat Reduction Assessment Index and protected areas

Threat Reduction

Threat reduction analysis conducted showed that at all levels of area, intensity and urgency, the national parks and wildlife reserves in Kibale Conservation Area had a higher overall average threat reduction (57.6%) compared to those in Queen Elizabeth Conservation Area (48.25%) (Table 4).

Specifically, habitat change/transition presented the highest threat with a paltry reduction of 1.25% in Queen Elizabeth Conservation Area and 16.25% in Kibale Conservation Area whereas boundary encroachment was the lowest threat with the highest threat reduction in both conservation areas with 86.25% in Kibale Conservation Area and 83.8% in Queen Elizabeth Conservation Area (Table 4).

Table -4: Threat Reduction in the Conservation Areas

		Percentage Threat reduction (%TR)						
Conservation Area	**Protected Area**	Habitat changes / transition	Wild fires	Human Wildlife Conflict	Poaching and wildlife trafficking	Population pressure /illegal activities	Boundary encroachment	**Average per PA**
Kibale Conservation Area	KNP	50	80	70	77.5	70	70	69.58
	SNP	5	40	60	50	50	90	49.20
	TSWR	5	50	50	65	80	90	56.67
	Katonga	5	50	60	50	70	95	55.00
	Overall average in KCA	*16.25*	*55*	*60*	*60.6*	*67.5*	*86.25*	*57.60*
Queen Elizabeth Conservation Area	QENP	5	60	20	50	80	80	49.17
	RMNP	0	40	80	40	40	80	46.67
	Kigezi NP	0	10	40	30	40	70	31.67
	Kyambura NP	0	90	50	75	80	95	65.00
	Overall average in QECA	*1.25*	*52.5*	*53.8*	*54.7*	*63.8*	*83.8*	*48.25*

Key: KNP=Kibale National Park ; SNP=Semuliki National Park; TSWR=Toro-Semliki Wildlife Reserve; KCA=Kibale Conservation Area; QENP=Queen Elizabeth National Park; NP=National Park; QECA=Queen Elizabeth Conservation Area

Further, wild fires had reduced by 55% in Kibale Conservation Area compared to 52.5% in Queen Elizabeth Conservation Area. Human wildlife conflict was still a great challenge in all the PAs with a reduction of 60% in Kibale Conservation Area compared to 53.8% in Queen Elizabeth Conservation Area. Human population pressure leading to illegal activities inside the protected areas had reduced by 63.8% in Queen Elizabeth Conservation Area compared to 67.5% in Kibale Conservation Area. Boundary encroachment by adjacent communities had reduced by 86.25% in Kibale Conservation Area compared to 83.8% in Queen

Elizabeth Conservation Area. Armed poaching and illegal wildlife trade in game meat and game products had reduced to 60.6% in Kibale Conservation Area compared to 53.8% in Queen Elizabeth Conservation Area (Table 4).

The national parks and wildlife reserves that lie entirely within Uganda had their threat reduction above 50% compared to those that are shared with Democratic Republic of Congo which had less than 50% (Table 4).

In addition, the focused group discussions revealed that other developments such as road construction, staff accommodation, setting up of tourist lodges and trails inside the national parks and wildlife reserves could have potential impact on the ecosystem. Further, transboundary issues, political interference, poor waste management (including wastes from oil palm processing in Semuliki National Park) and the impacts of climate change could also pose a threat in most protected areas.

Threat Reduction Assessment Index

Effectiveness of PA management in managing threats

Results of the comparison of staffing (staff per PA) and threat reduction assessment index (per PA) using Paired Samples *t* Test revealed that Staffing and TRA Index scores were moderately and positively correlated ($r = 0.590$, $p = 0.001$) and $t_7 = 1.412$, $p = 0.001$. On average, Staffing scores were 44.2275 points higher than TRA Index scores (95% CI [-29.83, 118.29]). From the box plot, the TRA Index values positively correlated with the staffing level in the PAs. Both variables appear to be symmetrically distributed (Fig 2).

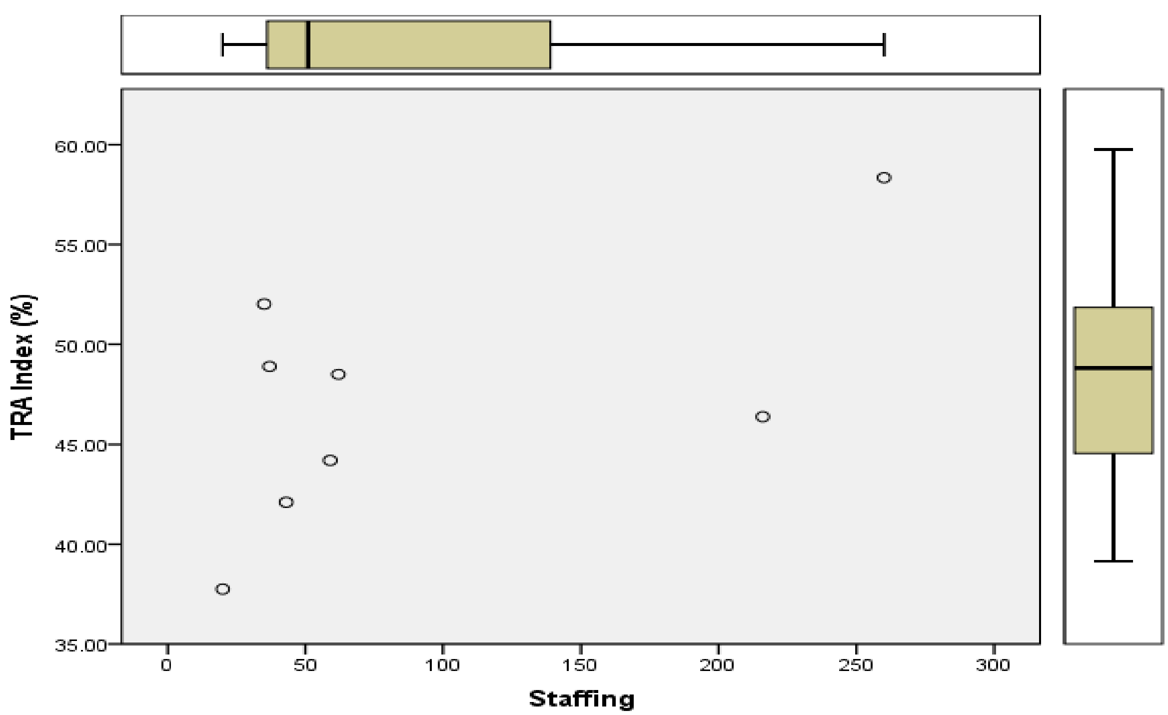

Fig. 2: Relationship between staffing and threat reduction assessment index

Threat Reduction Assessment Index and PAs

The threat reduction analysis looked at three criteria: area, intensity and urgency. Kibale Conservation Area had a higher overall average TRA index of 49.46% compared to Queen Elizabeth Conservation Area with 45.1%. At protected area level, Kibale National Park had the highest TRA Index of 58.35% and Kigezi Wildlife Reserve with had the lowest with 37.76%. However, threat reduction assessment indices were independent of the size of the protected areas (Fig. 3).

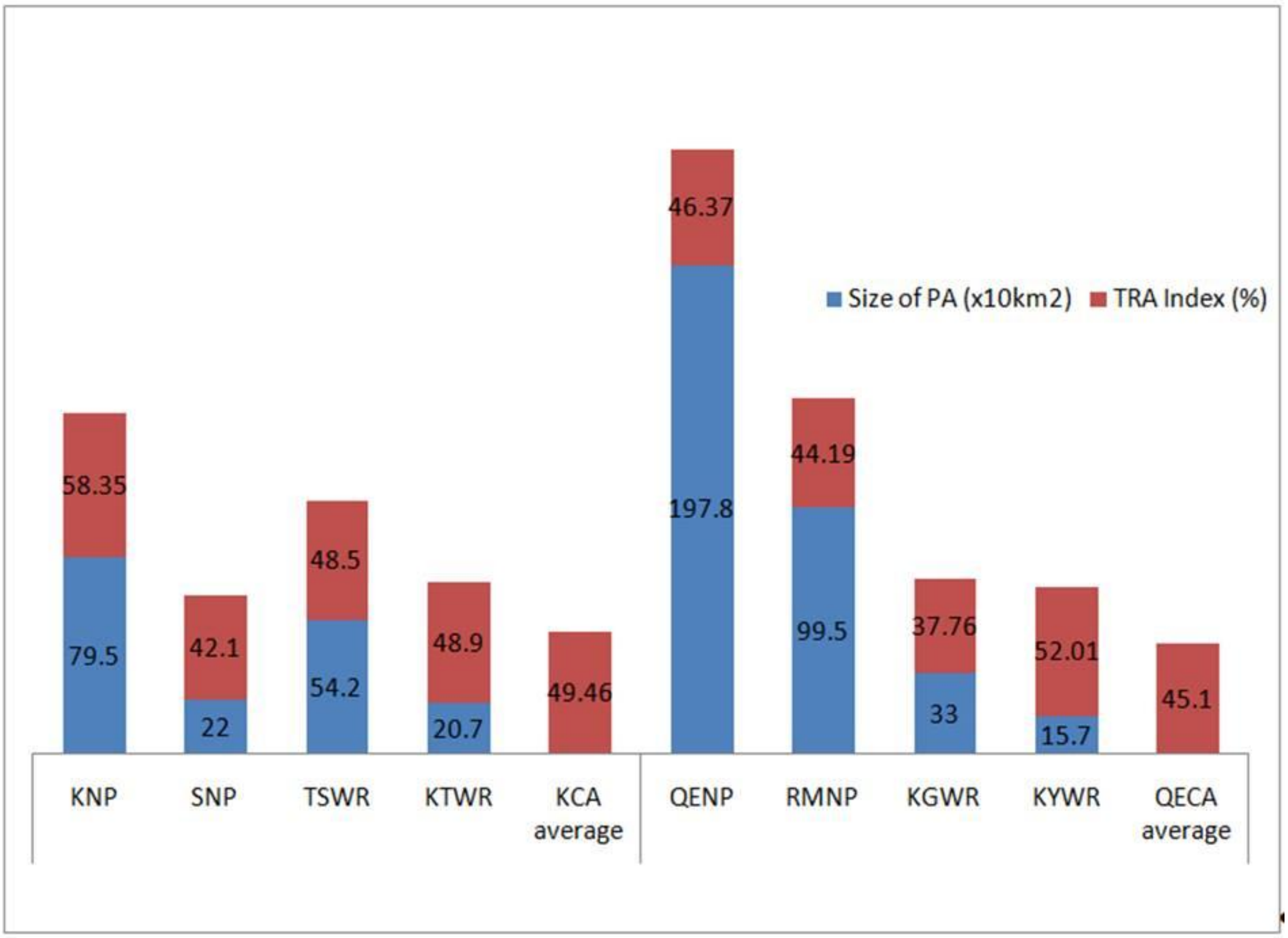

Fig. 3: Threat Reduction Assessment Indices in National Parks and Wildlife Reserves

Threat reduction and mammal population in Kibale Conservation Area

Anlysis of data from Kibale Conservation Area shows a general mammal population increase over the past decades. Specifically, in Kibale National Park, the population of the Black and White colobus monkeys increased from 7,346 in 2005 to 10,459 in 2010; the Baboon population increased from 11,603 in 2005 to 12,191 individuals in 2010. However, other primate populations have had a slight increase. The

Chimpanzee population has remained stable over the years (Fig. 4).

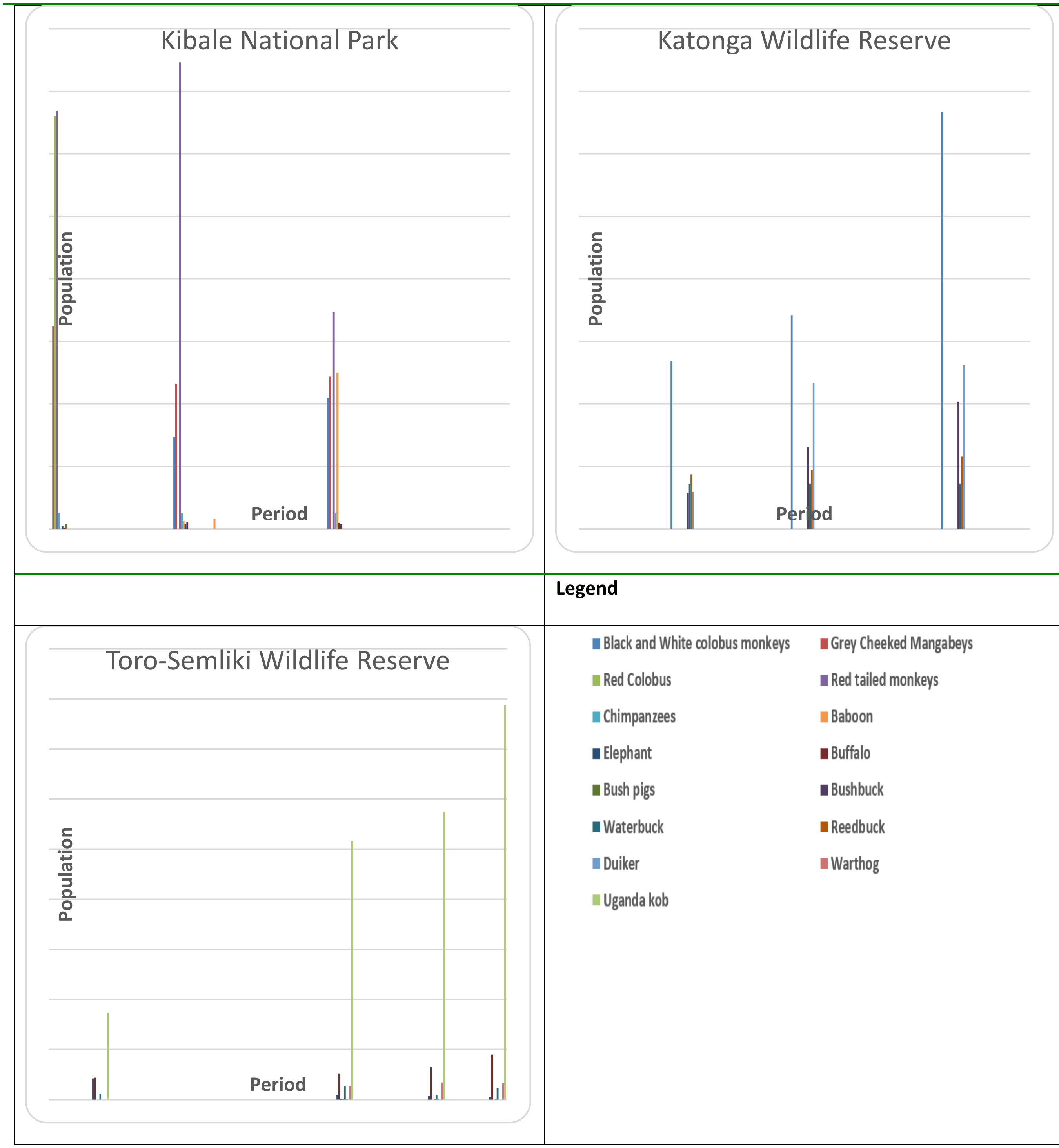

Fig. 4: Population Estimate for Primates and other mammals in Kibale Conservation Area (Raw data adopted from UWA, 2018)

In addition, the Elephant and Buffalo populations have had an exponential increase. The Elephant population has increased from 262 individuals in 2001 to 487 individuals in 2010; the buffalos from 124 individuals in 2001, to 402 individuals in 2010; and the Bush pigs were only estimated at 400 individuals in 2001. (Fig. 4) This general increase collaborates well with highest TRA Index of 58.35% recorded in KNP (Fig. 3).

In Katonga Wildlife Reserve, there was a steady increase in wildlife population from 2004 to 2013 (Fig. 4). The population of the Black and White colobus monkey increased from 1,342 in 2004 to 3,335 in 2013. Duiker population rose from 295 in 2004 to 1,169 in 2008. The Reedbuck and Waterbuck had a more or less stable growth in population over the years.

Similarly, the mammal population in Toro–Semliki Wildlife Reserve had a general increase. Specifically, the Uganda Kob population increased from 3,460 individuals in 1982 to 3,935 by 2015, the waterbuck population increased from 33 individuals in 1982 to through 58 individuals in 2002 to 112 by 2015, and the Buffalo population increased from 219 individuals in 2002 to 449 in 2015. (Fig. 4)

Threat reduction and mammal population in Queen Elizabeth Conservation Area

The elephant population in Queen Elizabeth Protected Area (QENP, KyamburaWR and Kigezi WR) reduced from 4,139 in 1969 to about 150 by 1980. It then started recovering until it reached 3018 individuals in 2012. Other wild animal populations have increased in QEPA (Fig. 5).

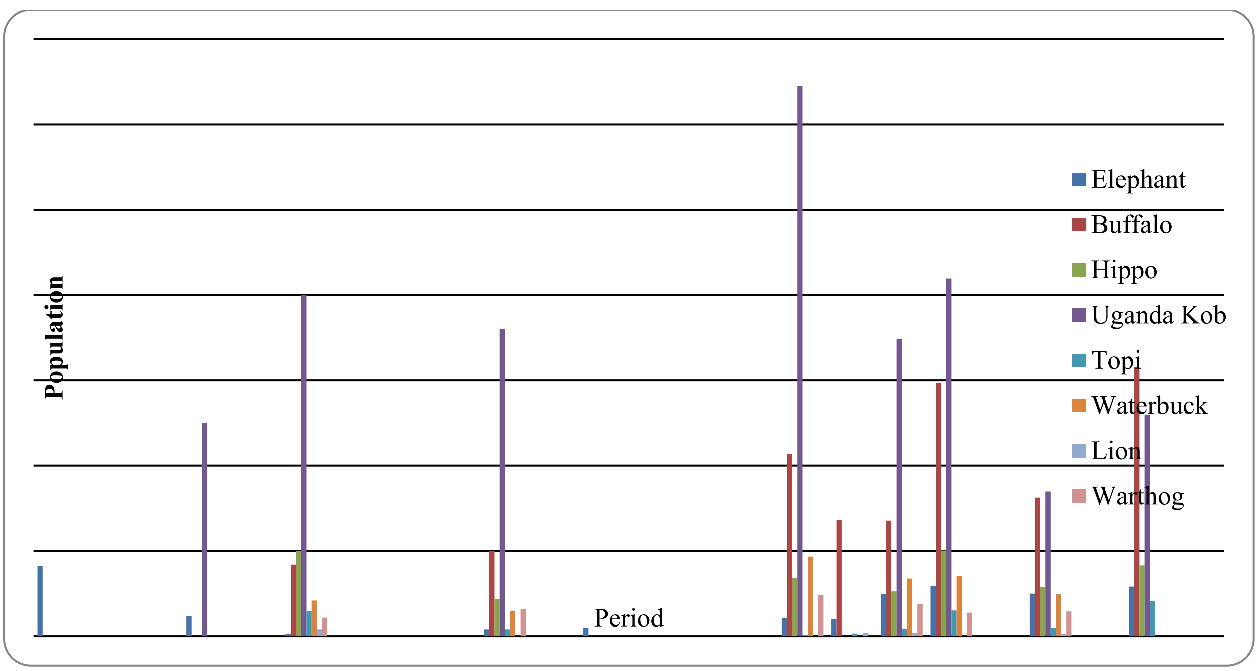

Fig 5: Medium to Large Mammal Population in Queen Elizabeth Protected Area (Raw data adopted from UWA, 2018)

Threat reduction and ecological integrity rating

The data indicators were analysed and various scores were assigned basing on the computed TRA Index in Table 4. Each indicator of ecological integrity was assigned a color score: dark green (TRA index 81-100%) for "acceptable" ecological integrity (very satisfactory), light green (TRA index 51-80%) for moderate ecological integrity (satisfactory), yellow (TRA index 21-50%) indicating a "concern," (dissatisfactory) and red (TRA index 0-20%) indicating "impaired" (very dissatisfactory) condition requiring immediate management action. (Table 5) Each national park and wildlife reserve had a score and each threat also had a score to show the level of threat reduction. On the whole, KNP and Kyambura WR had a "light green" score indicating moderate ecological integrity and hence satisfactory, while the rest of the PAs had each an average score of "yellow" indicating significant "concern" and therefore dissatisfactory (Table 5).

In addition, using a scoring of 1 to 4 (where 1- very dissatisfactory, 2- dissatisfactory, 3- satisfactory, and 4- very satisfactory) on the state of conservation of wildlife resources in the national parks and wildlife reserves, the responses from ecological experts, selected district local governments, Uganda Wildlife Authority, Wildlife Conservation Society-Uganda, and Ministry of Tourism, Wildlife and Antiquities indicated the overall performance of the national parks and wildlife reserves as dissatisfactory ($t(25) = 14.148, p = 0.000, \alpha = 0.001$).

Measures by the parks that enhance effectiveness and efficiency in addressing threats

In appreciation of the threats affecting wildlife conservation in the Conservation Areas, the study through the FGDs, identified management measures the parks have instituted to enhance effectiveness and efficiency in addressing threats and these include:

a) Undertaking wildlife related disease surveillance in and around the national parks and wildlife reserves and conduct community sensitization programmes on wildlife related diseases
b) Periodically monitoring wildlife and domestic animal movements to and from the national parks and wildlife reserves
c) Carrying out massive conservation sensitization and educational programmes,
d) Strengthening community conservation through the benefit sharing scheme, problem animal management, conservation education and awareness, and community participation in boundary management.
e) Gathering, analysing and acting on intelligence information on illegal activities inside the national parks and wildlife reserves.
f) Conducting cross border and or coordinated monitoring, control and surveillance patrols inside the national parks and wildlife reserves. This also involves cross border joint planning meetings, security operations.
g) Put in place ecological maintenance and restoration programs especially in Kibale National Park and Queen Elizabeth National Park which are intended to counteract threats to ecological integrity. These include eliminating through uprooting hyperabundant species such

as *Dichrostachys cinerea and Lantana camara* that threaten the ecological integrity of the park ecosystems.

Table- 5: Ecological Integrity Score Card using Data Indicators

Protected Area (PA)	Performance of Ecological Integrity using data indicators in the PAs									
	Large mammal population increase	Frequency of poaching incidences	Human wildlife conflict	Wild fires	Boundary encroachment	Resource harvesting	Zoonotic diseases	Habitat change	Road kills	Average rating per PA
Kibale Conservation Area										*Y*
KNP	Exponential	LG	LG	DG	LG	LG	DG	LG	LG	LG
SNP	N/A	LG	LG	*Y*	R		DG			*Y*
TSWR	General increase	LG	LG	LG	DG	DG	N/A	R	R	*Y*
Katonga WR	Exponential	LG	LG	LG	DG	LG	LG	R	N/A	*Y*
Queen Elizabeth Conservation Area										*Y*
QENP	General increase	LG	DG	LG	DG	DG	DG	R	LG	*Y*
RMNP	N/A	*Y*	DG	*Y*	DG	*Y*	N/A	DG	N/A	*Y*
Kigezi WR	General increase	*Y*	*Y*	R	LG	*Y*	DG	R	N/A	*Y*
Kyambura WR	General increase	LG	LG	DG	DG	DG	N/A	R	N/A	LG
Overall rating per indicator	LG	LG	LG	DG	LG	LG	DG	R	LG	*Y*

LG= light green; R =red; Y =Yellow; DG=Dark green; N/A= not applicable

DISCUSSION

The Kibale and Queen Elizabeth conservation areas are key wildlife protected areas within the Albertine Graben which house a very rich mammal biodiversity. However, over time, they are faced with key threats that degrade their habitats and conservation in general. The threats identified in this study are similar to those reported by other researchers from a number of countries in Africa (Laurance et al., 2012; DiMarco et al., 2014; Tranquilli et al., 2014; Taylor, 2015; MacKenzie, 2017; Ryan, 2017; Chibueze, 2018; Benı´tez-Lo´pez et al., 2019; Kolinski and Milich, 2021).

Human-wildlife conflicts occur worldwide, and human injuries are the most severe manifestations of these human-wildlife conflicts (Packer et al., 2005; Kabuusu et al., 2018). But the killing of livestock and the crop raiding by wildlife are by far the most widespread source of such conflicts (Allendorf et al., 2012; Andrade and Rhodes, 2012; Kabuusu et al., 2018). For instance, in Canada wolves are reported to have killed close to 3,000 domestic animals in 14 years, whilst elephants in India and China led to a reduction of approximately 14% and 48%, respectively of annual crop production (Madhusudan, 2003; Zang and Wang, 2003). In Tanzania, 86% of the persons living in wildlife buffer zones reported crop damage, while 10% reported the killing of livestock and poultry Kabuusu (2018), and baboons have always caused significant crop destruction in Uganda. The incidence of wildlife-associated human injuries increased in QENP between 2006 and 2010, and was mostly caused by hippos (Kabuusu et al., 2018).

Weather patterns define the corresponding farming activity and the level of threats. The dry season is characterized by limited pastures and water in QENP, consequently wild animals, particularly elephants, move out of the QENP into community areas in search of water and pasture, raiding crops in the process. It was also revealed that the dry season is also the harvest season, and farmers are injured because they stay outside at night for extended periods of time protecting their crops from elephants and thieves. This seasonal change, in both animal and human behavior, mirrors temporal differences in the incidence of wildlife-associated human injuries (Kissui, 2008). This study aimed at determining the threats to conservation and how they were being addressed. Data analysis and interpretation revealed major findings. The study established that socio-demographic factors of park staff mainly gender, age, education level and length of work experience play significant role in addressing threats to wildlife conservation. Equally, the socio-demographic factors of local communities adjacent the national parks and wildlife reserves mainly gender, age, education level and length of residence in the community play significant role in participating in programmes that address threats to wildlife conservation. This agrees with Kabir (2013) that recognition of gender roles in biodiversity management is an important step in the achievement of conservation and sustainable use of biological resources. PA management considers education as a key factor in empowering their staff with knowledge, skills and enhancing capacity and competence to conserve biodiversity. The park employees had the required skills in wildlife management and biodiversity conservation. In addition, length of work experience influences the level of understanding and implementing the mandate of PAs. This implies that the park employees are knowledgeable and could provide the needed information on threats to biodiversity conservation in the Park over the years. The presence of professionals corroborates the suggestion of Green (1999) that some industries required specially trained personnel to actualize set goals, and biodiversity conservation is a peculiar example.

The national parks and wildlife reserves in both KCA and QECA are faced with key primary threats that degrade their habitats and conservation in general. These include: i) habitat transition/changes due to invasive alien species, ii) wild fires, iii) human-wildlife conflicts arising from wildlife attacks to humans and livestock, and destroying crops, iv) poaching and illegal wildlife trade/trafficking in game meat and of recent in Ivory, v) increasing human population pressure leading to illegal activities/resource off-take, and vi) boundary encroachment through agricultural development and urbanization. Also, secondary threats mainly zoonotic and vector-borne diseases, transboundary issues, negative impacts of climate change, and infrastructure developments within the PAs constrain conservation efforts. These threats could be attributed to anthropogenic factors (including settlement, infrastructural development, agricultural expansion, resource off-take for livelihoods), and natural disturbances such as climate change, biological invasion, etc. These factors affect the aesthetic value, scenery, and also release wastes to the ecosystem. Further, inadequate funding to the sector, insufficient incentives to park staff, and inadequate patrol equipment also constrain conservation efforts.

The national parks and wildlife reserves in Kibale Conservation Area had a higher overall average threat reduction, and overall average TRA index compared to those in Queen Elizabeth Conservation Area. This higher overall average threat reduction compares well with the general increase in mammal population over the years in Kibale Conservation Area. This could be attributed to improved management of the park and law enforcement in particular combating poaching (UWA, 2018).

Despite the prevailing threats, the population of large mammals has generally increased over the past decades. This collaborates well with the TRA indices for each national park and wildlife reserve in each conservation area. The increase in mammal population is probably due to creation of both institutional and legal framework, and strengthened implementation of existing policies, laws and regulations. Specifically, the recovering mammal population in Queen Elizabeth Protected Area could be attributed to better security within Uganda, immigrations and successful breeding. This agrees well with UWA (2018) that improved PA management, increased vigilance through intelligence and patrols, and most importantly the peace, security and stability in the country and the region as a whole, and increased community conservation programs which have contributed to threat reduction. However, the low threat reduction performance of national parks and wildlife reserves shared with Democratic Republic of Congo is probably due to their transboundary nature, which presents with it varied management challenges (GVTC, 2017).

On the whole, the overall ecological integrity of Kibale and Queen Elizabeth Conservation Areas was rated “yellow indicating a “concern” and hence dissatisfactory, a condition that requires immediate management action. Specifically, both KCA and QECA had an average TRA index of less than 50%, an indication that both conservation areas only mitigate less of the PAs threats. This rating of the overall performance of the national parks and wildlife reserves as “dissatisfactory” by the ecological experts, park employees, district local governments, Uganda Wildlife Authority, Wildlife Conservation Society-Uganda, and Ministry of Tourism, Wildlife and Antiquities was a testimony that there was great “concern” to conserve wildlife resources. This level of performance could be attributed to the more emphasis the Wildlife

Agency puts on animal health issues and little on ecosystem health.

CONCLUSION

The study established that the national parks and wildlife reserves are majorly threatened by habitat transition/changes, wild fires, human-wildlife conflicts, armed poaching and illegal wildlife trade/trafficking, increasing human population pressure, and boundary encroachment through agricultural development and urbanization. Other threats are zoonotic and vector-borne diseases, transboundary issues, negative impacts of climate change, and infrastructure developments within the PAs which constrain conservation efforts.

Creation of both institutional and legal framework, and strengthening implementation of existing policies, laws and regulations is key to biodiversity conservation success. Protection of the integrity of wildlife conservation areas requires an integrative approach of interventions that focus on both animal health, and ecosystem health at national and transboundary level. Reduction in threats affecting wildlife conservation areas calls for a multidisciplinary approach involving local communities, park management, and security agencies. Therefore, improved park management, increased vigilance, and peace, security and stability in a country or region are prerequisites to achieve conservation of wildlife and other biodiversity. Various management approaches to enhance effectiveness and efficiency in addressing threats must include, but not limited to, undertaking wildlife related disease surveillance, periodically monitor wildlife in and outside the national parks and wildlife reserves, conduct conservation awareness and education, strengthen community conservation through the benefit sharing programme, strengthen intelligence information on illegal activities, strengthen adaptive management to address threats to ecological integrity.

Recommendations

The wildlife agency should strengthen adaptive management as a strategy to restore all degraded areas inside the national parks and wildlife reserves and carry out periodical environment audits..

The wildlife agency should strengthen law enforcement and national-level coordination with the community and concerned stakeholders to combat poaching and other illegal activities in the park.

Finally, more research should be conducted to investigate the impact of tourism infrastructure development on ecological integrity of the national parks and wildlife reserves.

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Authors' contributions

J.K. initiated and shared the research idea, drafted the concept, coordinated the data collection and analysis and wrote the first draft of the manuscript. N.M.M and C.K.T assessed the draft concept of the manuscript, made conceptual guidance to collect right data and made critical intellectual adjustments on the first manuscript to make it a clear scientifically and logically drafted manuscript. All authors assessed and approved the final copy of the manuscript for submission.

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Prevalence and community awareness of Bovine Trypanosomiasis in Wolaita Zone Kindo Koysha Woreda, Southern Ethiopia

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KEYWORDS:

Trypanosomiasis;
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Bovine

Research article

ABSTRACT

A cross-sectional study was carried out from October 2018 to April 2019 in Kindo Koysha Woreda of Wolaita Zone, Southern Nation Nationalities and People Region (SNNPR), Ethiopia. The general objectives were to find the prevalence and assess the community awareness on bovine trypanosomiasis and to identify predominant trypanosome species. Blood from marginal ear vein was collected from a total of 220 cattle for Packed cell volume (PCV) determination and trypanosome detection. Accordingly, the overall prevalence of bovine Trypanosomiasis in the area was 5.91% on Buffy coat examination. Of which, 61.57% (n=8), 30.76% (n=4) and 7.69% (n=1) were because of *T. congolense* or *T. vivax* or both species, respectively. The mean PCV values recorded were 23.77% in parasitemic and 28.27% in aparasitemic animals. The focus group discussion indicated that trypanosomiasis (Shulula) is the most important problem affecting the animals and hindering agricultural activity in the area. Generally, both focus group discussion and hematological findings revealed bovine trypanosomiasis is the major constraint for the livestock production in the area. So attention should be given to control trypanosomiasis and its vectors.

INTRODUCTION

In Ethiopia, agricultural development is considered a priority by the government for stimulating overall economic growth, reducing poverty and achieving food security. The agricultural sector of Ethiopia accounts for about 42% of GDP and between 80–85% of employment (MoFED, 2012).

Within agriculture, the livestock subsector provides an opportunity for further development. The sheer size of the national livestock herd, one of the largest in Africa, makes it a resource with potential to contribute

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significantly to national development, including poverty reduction. The Central Statistical Agency (CSA) survey of 2016 showed that the total cattle population of Ethiopia is about 59.5 million. Moreover, about 30.7 million sheep and 30.2 million goats are estimated to be found in the country, while the total poultry population is estimated to be about 59.5 million chickens (CSA, 2016).

The livestock subsector is also already a major contributor to the overall economy. The livestock sector contributes 19% of the GDP, and 16–19% of the foreign exchange earnings of the country (MoA 2012). It contributes some 35% of agricultural GDP; or 45% if indirect contributions are taken into account (Shapiro et al., 2017).

With a rapidly growing population, increasing urbanization, and rising incomes, domestic demand for meat, milk and egg is expected to increase significantly in the foreseeable future. Furthermore, the country's geographic location offers substantial opportunities for exportation, thus earning foreign exchange from livestock products, especially of red meat to the Gulf and within Africa, as well as leather, honey and other livestock products to Europe(Shapiro et al., 2017).

The livestock sector can also be a major contributor to poverty reduction by improving the livelihoods of rural people. Approximately 85% of Ethiopia's population is rural based, and livestock supports the livelihoods of about 80% of rural people (Shapiro et al., 2017). However, the income of 30% of the rural population is below the poverty line (MoFED, 2013). Livestock perform multiple functions in the rural household economy. Besides employment, livestock provides protein rich food, income for everyday expenses and social obligations, near liquid assets, a store of wealth for savings, manure for crop production and soil fertility, and transport (Shapiro et al., 2017).

Livestock development also has the potential to positively impact urban consumers through lower animal product prices. Despite large livestock population, Ethiopia fails to optimally utilize this resource due to different constrains facing the livestock subsector. Shortage of nutrition, reproductive insufficiency, management constraints and animal disease are the major constraints. One of the diseases hampering the livestock subsector is trypanosomiasis (Melak and Tewodros, 2018). Trypanosomiasis is a widely spread protozoan disease complex which affects cattle and other wide range of hosts in sub Saharan Africa. The major pathogenic tsetse transmitted trypanosome species are *Trypanosome congolense, T.vivax* and *T. brucei* in cattle, sheep and goats and *T. simiae* in pigs. Animal trypanosomiasis is also encountered outside the tsetse fly belt, where the most important pathogenic trypanosome species, *T. vivax* and *T. evansi*, are transmitted mechanically by biting flies, while *T. equiperdum* is transmitted sexually. The principal domestic animals affected by *T. evansi* are camels, pigs, water buffaloes and cattle. *T.equiperdum* causes the disease in horses and donkeys (Nantulya et al., 1986). The course of the disease may run from a chronic long lasting to an acute and rapidly fatal depending on the vector-parasite-host interactions. The disease is mainly characterized by intermittent fever, progressive anaemia, and loss of condition of susceptible hosts which if untreated leads to heavy mortalities (Bourn et al., 2001).

In Ethiopia, trypanosomiasis is widespread in domestic livestock in the Western, South and South western lowland regions and the associated river systems (Abay/Dedessa, Ghibe/Omo and Baro/Akobo and rift valley) (Abebe, 2005), limiting livestock productivity and agricultural development in the country. Currently, about 220,000 Km2 areas of fertile land are infested with five species of tsetse flies namely *Glossina pallidipes, G.morsitans morsitans, G. fuscipes, G. tachinoides* and *G. longipennis* (NTTICC, 2004). Six species of trypanosomes are recorded in Ethiopia and the most trypanosomes, in terms of economic loss in domestic livestock are the tsetse transmitted species: *T. congolense, T. vivax* and *T. brucei* group (Abebe, 2005). Trypanosomiasis was considered to be an important disease of cattle in different parts of the country (Mussa, 2002; Tesfaye, 2002; Cherenet et al., 2004; Sinshaw, 2004; Shimelis et al., 2005; Bitew et al., 2011). Even though, trypanosomiasis is an economically important disease, few studies were done in Ethiopia as well as in Wolaita Zone Kindo Koysha Woreda. Therefore, this study was conducted to determine the prevalence of bovine trypanosomiasis, to identify predominant trypanosome species involved and to recognize indigenous knowledge and correlate it with modern science in Kindo Koysha Woreda.

MATERIALS AND METHODS

Description of the study area:

The study was conducted in Kindo Koysha woreda of Wolaita zone, Southern Region of Ethiopia. It is located at about 420 Km of south west of Addis Ababa located at 7°58” N and 37°14” latitude and 37°56” E longitude and it has an altitude of 600-1700 meters above sea level. and its total area is estimated to be 17,187 hector of land. The distribution of rain is bimodal, with short rainy season extend from January to April and long rains from June to mid-September. The average annual rainfall is 904 mm, the maximum and minimum daily temperature is 29.20 and 21°C respectively. The vegetation is savanna type with scattered bush. The livestock populations that are found in Kindo Koysha Woreda include cattle, sheep, goat, horses, mule, donkey and poultry. Among these animals, cattle are the dominant species raised in the area and are estimated to be 174,346 (CSA, 2009).

Study design, sample size and sampling method:

Cross sectional study was conducted to determine the prevalence of bovine trypanosomiasis. 95% confidence interval and 5% precision was considered to calculate the sample size and 6.3% expected prevalence was taken (Adale and Yasin, 2013). The sample size was determined by using the formula given by Thrusfield (2005). Even though the sample size was calculated to be 91, a total of 220 animals were included in the current study to increase precision.

Study population:

Cattle population of Kindo Koysha Woreda which is managed under traditionally reared management system was selected to determine the prevalence of bovine Trypanosomiasis. Both local/indigenous and exotic breeds of cattle in the study area (Dada kariya, Fajanamata, Moliticho) were considered as study population. The study animals were selected by using random sampling method by taking breed, age, sex and body condition into account. The animals examined were categorized into different age groups as less than 2 years (young), between 2 and 4 years (medium) and greater than 4 years (adult) according to their teeth dentition (Johnson, 2003). The body condition of animals was also grouped based on criteria described by Nicholson and Butterworth (1986) and they also categorized into poor, medium and good.

Study Methodology

Parasitological and Hematological Survey of Bovine Trypanosomiasis:

Buffy Coat Technique:

Blood was collected from an ear vein using heparinized micro haematocrit capillary tube and the tube was sealed. A heparinized capillary tube containing blood was centrifuged for 5 min at 12,000 rpm. After centrifugation, trypanosomes were usually found in or just above the Buffy coat layer. The capillary tube was cut using a diamond tipped pen 1 mm below the Buffy coat to include the upper most layers of the red blood cells and 3 mm above to include the plasma. The content of the capillary tube was expressed on to slide, homogenized on to a clean glass slide and covered with cover slip. The slide was examined under ×40 objective for the movement of parasite (Paris et al., 1982).

Measuring of Packed Cell Volume (PCV):

Blood samples were obtained by puncturing the marginal ear vein with a lancet and collected directly into a capillary tube. The capillary tubes were placed in micro haematocrit centrifuge with sealed end outer most. The tube was loaded symmetrically to ensure good balance. After screwing the rotary cover and closing the centrifuge lid, the specimens were allowed to centrifuge at 12,000 rpm for 5 min. Tubes were then placed in haematocrit and the readings were expressed as a percentage of packed red cells to the total volume of whole blood. Animals with PCV < 24% were considered to be anemic (Murray et al., 1988).

Focus group discussion:

Rural communities have a wealth of indigenous knowledge and skills related to diseases, including good diagnostic skills and an awareness of modes of disease transmission. It is imperative to make the best use of this knowledge and develop appropriate disease surveillance systems in rural areas. Such systems should be action oriented and result in disease control activities that are designed in partnership with livestock keepers (Catley, 2005). This study used focus group discussion technique to collect epidemiological information and intelligence about diseases of livestock especially bovine trypanosomiasis. The focus group discussion incorporated eight groups having 8-12 participants in each group.

Data management and analysis tools:

Raw data on individual animals and parasitological examination results were stored in MS excel spread sheets to create data base and transferred to Stata 11 software programs for data analysis. Chi square was used to compare the prevalence of trypanosome infection in different variables like kebeles / village, breed, age, sex and body condition, while student-t test was utilized to compare the mean PCV of the infected animals and that of non-infected animals. Significance difference was set at $p < 0.05$ and 95% confidence level.

RESULTS

Results of focus group discussion:

According to the data from the group discussion, Trypanosomiasis is the predominant livestock disease in the Kindo Koysha followed by Babesiosis (14.75%), Blakleg (13%) and others (Table 1).

Table-1: Common cattle diseases with its respective proportional

Disease	Prevalence %
Shulula (Trypanosomiasis)	35
Tilikiya/tintichuwa (Blackleg)	13
Duluwa (Anthrax)	6.375
Aheera (Babesiosis)	14.75
Shattuwa (Skin diseases)	8.125
Danquwannecuuchcha (Tick and lice infestation)	7.5
Ullogiddoguxxuniya (GIT Parasite)	7.625
Duma dummahargiya (others)	7.625

Based on the response of the rural communities, the prevalent diseases in the area cause direct and indirect negative impacts on the cattle and their products (Table 2).

Table-2: Negative Impacts of diseases on the animals and animal's product

Diseases	Milk (%)	Meat (%)	Skin (%)	Dowry (%)	Abortion (%)	Decrease price (%)	Treatment cost (%)	Total loss (%)
Trypanosomiasis	23	14.5	1.5	9	10.75	13	24.5	3.75
Blackleg	6.25	5	1.75	1.75	2	-	34.5	48.75
Anthrax	-	-	-	-	-	-	1	99
Babesiosis	27	17.5	3	5	12.5	7	20	8
Skin diseases	15	12	23	9	-	20	21	-
Tick & lice infestation	21	16.25	16.75	8	2	18	17	1
GIT Parasite	24	22.5	-	7	-	15	31.5	-
Others diseases	15.5	12.5	5	6	11	8	22	20

According to the Wolaita Culture the year is divided into three seasons such as Boniya (Bega) which includes the months from October to February, Badheessa (Belg) from March to May and Silla (summer) which contains months from June to September. According to the respondents, the prevalent diseases in the area have different seasonality however majority of these diseases were observed during 'belg' and summer (Table 3).

Table-3: Disease occurrence in the different seasons of the year and age group of cattle

Disease	Age group			Season		
	Calf (%)	Young (%)	Adult (%)	'Bega' (%)	'Belg' (%)	Summer (%)
Trypanosomiasis	10	29	61	39.6	33.7	26.7
Blackleg	7.5	36	56.5	9.55	53.75	36.7
Anthrax	6	33	61	7.5	63	29.5
Babesiosis	12	31	57	19	49.5	31.5
Skin diseases	14	40	46	37	30.5	32.5
Tick and lice infestation	35	34	31	20	50	30
GIT Parasite	37	28	35	20	50	30
Others diseases	20	35	45	22	50	27

The major actions taken by the society to overcome the impacts of the prevalent diseases are detailed in the table 4.

Table- 4. Major disease prevention and control measures applied in the study area.

Disease	Vaccination (%)	Spraying (%)	Drug (%)	Traditional medicine (%)
Trypanosomiasis	-	38	62	-
Blackleg	50	-	37	13
Anthrax	96	-	4	-
Babesiosis	4	3	68	25
Skin diseases	29	25	46	-
Tick and lice infestation	-	72	25	3
GIT Parasite	-	-	95	5
Others diseases	44	8	41	7

Results of parasitological survey:

Prevalence: In this study a total of 220 cattle were examined for the presence of bovine trypanosomiasis. Out of these 220 cattle; 13 were found to be positive for bovine trypanosomiasis that results in the overall prevalence of 5.9%. Of which 61.57% were due to *T. congolense* and 30.76% were due to *T. vivax* whereas the rest 7.69% were due to mixed infection (Table 5). But there was no significant difference ($p>0.05$) between the prevalence of the different trypanosome species.

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Table -5. Relative proportion of Trypanosome species in the three kebeles

Kebeles	Number positive	Trypanosome species , n(%)			Proportion (%)	χ^2	P- value
		T.congolense	*T.vivax*	Mixed			
Fajenamata	7	4(30.77)	2(15.38)	1(7.69)	53.8	1.58	0.813
Moliticho	5	3(23.08)	2(15.38)	0	38.46		
Dadakariya	1	1(7.69)	0	0	7.69		
TOTAL	13	8(61.57)	4(30.76)	1(7.69)	100		

The highest prevalence of trypanosome infection was found in Fajenamata kebele (7%) followed by Moliticho (6.94%) and Dadakariya (2.08%). However, there was no significant difference (p>0.05) in the prevalence among the kebeles (Table 6). The prevalence of trypanosomiasis in male and female cattle were 5.31% and 6.54% respectively (Table 6). However, the difference in the prevalence between the two sexes was found to be statistically insignificant (p>0.05).

Table- 6. Prevalence of Trypanosome infection among the categories of the considered risk factors

Variables		Number examined	Number positive	Prevalence (%)	95% CI
Kebeke	Fajenamata	100	7	7.00	1.95 – 12.05
	Moliticho	72	5	6.94	1.00 – 12.89
	Dadakariya	48	1	2.08	-2.02 – 6.19
Age	< 2 years	15	0	0	-
	[2-4] years	95	5	5.26	0.72 – 9.80
	> 4 years	110	8	7.27	2.37 – 12.17
Sex	Female	107	7	6.54	1.81 – 11.27
	Male	113	6	5.31	1.13 – 9.49
Body condition	Poor	55	8	14.54	5.09 – 24.00
	Medium	120	5	4.17	0.56 – 7.78
	Good	45	0	0	-

CI=confidence interval

Hematological Finding:

The packed cell volume (PCV) of parasitemic animals falls in the range of 21.0 - 25.0% while in aparasitemic cattle was in the range of 21.0-37.0%. The mean PCV for the Parasitemic animals was 23.76%, whereas 28.27% for the aparasitemic animals. Moreover, the difference in the mean PCV of the parasitemic and aparasitemic groups was statistically significant (P<0.05) (Table 7).

Table -7. The packed cell volume of parasitemic and aparasitemic cattle in the study area

Status	No. Examined	Mean PCV(%)	Std. Err.	Std. Dev.	95% Conf. Interval]	t- test	P-value
Aparasitemic	207	28.271	0.245	3.52	27.78 - 28.75	4.575	0.0000
Parasitemic	13	23.770	0.395	1.42	22.91 - 24.63		
Total	220	28.005	0.242	3.59	27.53 - 28.48		

DISCUSSION

The results of the focus group discussion revealed that trypanosomiasis, locally called as 'Shulula', was reported to be the most important livestock constraint limiting the overall agricultural activity and livestock productivity in the study area. Similar result was also reported by Afewerk (1998) and Tewelde (2001) in the western and northwestern parts of Ethiopia where cyclically (tsetse) transmitted trypanosomiasis is the primary problem for livestock productivity and agricultural development.

Although trypanosomiasis occur throughout the year, major infections are observed in Boniya (Bega) (39.6%), Badheessa (Belg) (33.7%) and Silla (summar) (26.7%) based on the local calendar Afewerk (1998) and Tewelde (2001) reported consistent results. According to the result of focus group discussion, the occurrence of trypanosomiasis is higher in the adult (61%) followed by young (29%) and in calves (10%). This might be due to the management system in the area that the adult and young animals stay around Omo River basin for grazing where there were tsetse fly population exists, while the calves are confined at home and not exposed for tsetse. Also the discussion revealed that, trypanosomiasis control and prevention methods depends as much as 62% in the use of different trypanocidal drugs and the rest 38% relay on spraying of insecticides.

The overall prevalence of bovine trypanosomiasis recorded in the current study (5.91%) was much lower than the previous findings. Different researchers reported different prevalence in different parts of Ethiopia. Abraham and Tesfaheywot, 2012; Ataro et al., 2015; Tamirat et al., 2016; Dejen, 2017; Shimels and Bosona, 2017; Megersa et al., 2019 who reported 27.5%, 21.33%, 26.82%, 26.3%, 21.5% and 12.24% in Wozeka grid on the southern part of Arbaminch, Konta Special woreda, Southern Ethiopia, Loma woreda, Dawuro zone, Southern Ethiopia, Nyangatom Woreda of South Omo, SNNPRS, Ethiopia, Botor Tolay district, Bombasi Woreda, western Ethiopia and Jimma Zone, respectively. This might be due to the difference in using control methods of trypanosomiasis, climate and ecological conditions such as altitude, rainfall, and temperature and livestock management system. This is comparable with the previous studies of 6.3% (Adale and Yasin, 2013) in Wolaita Zone KindoKoysha district of Ethiopia and 8.3% (Eshetu et al,. 2017) in Mareka district of Dawuro Zone, Southern Ethiopia.

The lower prevalence of bovine trypanosomiasis in the current study area might be due to periodical measures taken by the government to control tsetse population from the area. This may be due to increased and frequent use of different trypanocidal drug and easy accessibility of trypanocidal drugs, even there is home to home treatment service. Various studies reported the most prevalent trypanosome species in tsetse infested areas of Ethiopia were *T. congolense* and *T. vivax* sometimes *T. brucei* and mixed infection in some extent (Fikru et al., 2012; Leta et al., 2016). The finding of this study revealed that the majority of the infection was due to *T. congolense* (61.57%), *T. vivax* (30.76%) and the least was infection by mixed infection (*T. congolense* and *T. vivax*) (7.69%).

The higher infection rate of *T. congolense* in the study area was in agreement with trypanosome species prevalence data from other tsetse infested region of Ethiopia. Abraham and Tesfaheywot, (2012); Adale and Yasin, 2013 and Megersa et al., 2019 reported *T. congolense* 61.4%, 58.8% and 59.6% in Wozeka grid on the southern part of Arbaminch, Wolaita Zone Kindo Koysha district of Ethiopia and Botor Tolay district, Jimma Zone Ethiopia respectively. This study revealed the infection rate of *T. vivax*is 14.2%, 29.4% and 25.5% respectively. The species specific trypanosomiasis prevalence rate in Bombasi Woreda, Western Ethiopia was; *Trypanosome congolense* 51.76%, *Trypanosome vivax* 28.23%, *Trypanosome brucei* 11.76% and mixed 8.23% (Shimels and Bosona, 2017).

In the present study, T. *congolense* was the predominant species in the study area which may be due to the development of better immune response to *T. vivax* by the infected animal (Leak et al., 1999). However, it was statistically insignificant in the study area ($p>0.05$). Vector born trypanosome species are disseminated in most parts of Western and South Western parts of Ethiopia (Roeder et al. 1984).

The infection rate of female is higher than male cattle in the present study but there was no statistical difference ($P=0.698$). This result is comparable with the findings of Dejen, (2017) and Megersa et al., (2019). The present study is in agreement with the previous reports of Konta special woreda; which was 20.7% in female and 17.3% in male cattle which shows no significant statistical variation (Migbaru and Desta, 2015). Similar findings were also reported by Daya and Abebe (2008) and Tadesse and Tsegaye (2010). This may be due to the physiological difference between sex groups. The possible explanation for higher prevalence of trypanosomes in female animals in the present study area might be the fact that female animals were more likely exposed to tsetse flies as they were always released to common grazing sites of tsetse infestation, in contrast to male animals as they were kept in the house after ploughing and have little chance to be exposed to tsetse flies (Eshetu et al,. 2017).

The prevalence of trypanosomiasis on different age groups was 0%, 5.26% and 7.27% in young (<2 years), medium ($2\leq x\leq 4$) and adult (>4), respectively. The difference in prevalence among the different age groups was not statistically significant ($p>0.05$). This might be due to the less exposure of calves for the tsetse flies, since most of them were confined at homes whereas as the young and the adults move far distance in search of feed and water. Such areas are widely known for their high tsetse population thereby this may increase their probability to contract with the agent (Adale and Yasin, 2013).

The higher prevalence of trypanosomiasis in cattle with poor body conditioned than in medium and good body conditioned animals in the study area was recorded and it was comparable with the results of Abraham and Tesfaheywot et al. (2012) in Arbaminch area and, Adale and Yasin (2013) in Wolaita Zone Kindo Koysha district, Southern Ethiopia. This might be due to the fact that poor body condition animals are susceptible to the infectious disease and reduced performance of the animals may be created by lack of essential nutrients and poor management by the animal owner.

Regarding the PCV determination, the mean PCV of the parasitemic animals (23.76%) was lower compared to aparasitemic animals (28.27%) and the difference was significant ($p<0.05$). Likewise, Van den Boossche and Rowlands (2001) stated that the average PCV of parasitologically negative animals was significantly higher than that of parasitologically positive animals.

CONCLUSION & RECOMMENDATIONS

Based on focus group discussion bovine trypanosomiasis is the major constraint for the livestock production in the area. The current study also revealed an overall prevalence of 5.91% for bovine trypanosomiasis based ob Buffy coat examination. The predominant trypanosome species found were *T. congolense and T. vivax*. The mean PCV values indicated the trypanosome infection has been found to cause anemia in cattle. According to the community, bovine trypanosomiasis is the major problem than other livestock diseases in the area.

To reduce the prevalence of the disease in the area, appropriate tsetse and trypanosomiasis control action should be integrated and strengthened. Moreover, further studies on the tsetse challenge and the economic impact of trypanosomiasis on the agricultural productivity should be conducted

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Climate change, freshwater ecosystems and inland fisheries: implications for the developing nations

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ABSTRACT

Freshwater ecosystems are vital for ensuring drinking water supplies, bio-resources that support livelihood, and a wide array of ecosystem services. Further, they are among the key components in achieving the United Nations Sustainable Development Goals (UN SDGs) set for the year 2030, including poverty reduction, food security, clean water and sanitation, conservation of biodiversity and climate action. The aquatic ecosystems globally are susceptible to the impacts of climate change much more than terrestrial and marine ecosystems, impacting the livelihood of fishers and farmers depending on it. Climate change is expected to adversely affect the sustainable development capabilities of many Asian and African nations by putting more pressures on natural resources and the environment. This article reviews the impact of climate change on freshwater ecosystems and fisheries and addresses the key adaptation, mitigation and management strategies to address the issue of climate change.

INTRODUCTION

Water is inextricably linked to the development of all societies and cultures and is an integral component in all the major pillars of sustainable development including economic, social and environmental. Moreover, healthy freshwater ecosystems provide both direct and indirect services to mankind and serve as key components in achieving the United Nations Sustainable Development Goals (SDG) set for the year 2030. Unsustainable development pathways and anthropogenic interventions such as population growth, urbanization, changing patterns of consumption and climate change have affected the quality and quantity of water availability across the globe, despite the increasing demands for freshwater and the resources therein (WWAP, 2015).

One of the requirements for sustainable development of water resources is to balance the gap between demand and supply, both in terms of quality and quantity. However, climate

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change may affect both sides of the balance, thereby add to the challenges (IPCC, 2014). Global warming and the resultant climate change is occurring at an unrivalled pace in human history (Barros et al., 2014), showing progressive threat to freshwater ecosystems (O'Gorman et al., 2014; Li et al., 2016).

Under current climate projections, most freshwater ecosystems will face ecologically significant climate change impacts by the middle of this century (IPCC, 2014). Most freshwater ecosystems have already begun to feel these effects. These impacts will be largely detrimental to the existing freshwater species and human livelihoods. The impact of climate change may vary in different types of aquatic ecosystems, and also within the same ecosystem such as a river and many impacts remains to be documented in many countries of Asia and Africa.

Considering the world's weather-and climate-related disasters, Asia has encountered the maximum, resulting in colossal economic loss (IPCC, 2012). Freshwater species populations have declined on an average by 50 per cent, when compared to 30 per cent for marine and terrestrial species between 1970 and 2000 (MEA, 2005). Climate change is expected to adversely affect the sustainable development capabilities of most Asian and African countries by aggravating pressures on natural resources and the environment. Owing to the thick population and considerable economic dependence on inland fisheries in Asia, freshwater resources need to be carefully assessed and monitored across the wide range of climates (Pfister et al., 2009). According to the report of the Inter governmental Panel on Climate Change (IPCC), global warming will lead to "changes in all components of the freshwater system". Water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change (Bates et al., 2008). According to Sharma et al. (2015), during 2014-2015 the food production in India declined substantially due to droughts, flood, hailstorms and unseasonal rains. Climate change is expected to adversely affect the sustainable development capabilities of many nations by putting more pressures on natural resources and the environment. India stands second in contributing to the global inland fish production and therefore any impacts of climate change on aquatic ecosystems as well as fisheries should be given due recognition.

Blessed with diversified agro-climatic conditions, Kerala state of India is rich in aquatic resources. It has 44 rivers and their numerous tributaries, canals, lakes, ponds etc. which have the potential to emerge and develop and also to contribute to the livelihood and nutritional support to the country. The rivers in Kerala entirely monsoon-fed, some of them nearly turn into rivulets in summer. The state is a part of Western Ghats Sri Lanka biodiversity hot spot with greater endemism of freshwater fauna. Around 130 species of freshwater-dependent fauna belonging to five taxonomic groups (fish, amphibians, crabs, shrimps and odonates) are endemic to the region, of which 25 per cent have a high risk of extinction (Raghavan et al., 2016). Even though the wetlands in dry environments are considered productive, the biodiversity hotspots areas, their flora and fauna are under threat of extinction as the runoff decreases and wetland dries out (Zacharias and Zamparas, 2010).

Even a very small increase in precipitation will have pronounced effects on freshwater ecosystem. The part of Konkan coast and south Kerala are considered as the most vulnerable stretches by India's Second National Communication to United Nations Framework Convention on Climate Change (UNFCCC) (Anonymous, 2012). The natural resources from lakes, rivers, ponds, wetlands, reservoirs and backwaters of Kerala are depleting due to habitat modification and alterations, pollution, eutrophication, invasive species and climate change. These negative effects definitely have adverse impact on the ecosystem. Being a small coastal state located in the tropical region; the climate of Kerala is not exposed to severe fluctuation in terms of most of the meteorological factors except rainfall (Niyas et al., 2017). The rainfall data from the meteorological department also stipulate the declining pattern of northwest and southeast monsoon especially in the hilly areas of south Kerala during the last 60 years. The state receives adequate rainfall (average 3000mm), most of it is obtained via southwest and northeast monsoons. Kerala is advancing towards water crisis owing to the variability in temporal and spatial distribution of rainfall and the steep slope of the state allows almost 75% of rainwater to flow to sea at a much faster rate before exploitation (Nair, 2016).

Most of the species adapt to environmental changes but even then it leads to local or global extinctions and biodiversity loss (Gallo et al., 2017). Unlike marine ecosystem, inland bodies are markedly vulnerable to the climate change. Rise in water surface temperature, changes in primary production and changes in fish stock distribution disrupts habitat destruction, aquatic flora and fauna and prey predator composition which will have a nugatory influence on the resources leading to depletion of fish stock and will definitely jeopardise the livelihood of fishers. All these points towards the need for better policies and framework for dealing matters related to the impacts climate change on aquatic ecosystems and inland fisheries.

DRIVERS OF CHANGE

The freshwater ecosystems are affected by several stressors, of which climate change is by far more critical (Garner et al., 2017). Climatic drivers are the temperature, precipitation, evaporation, sea level, carbon dioxide concentration etc. whereas economic developments, urbanization, increase in population and land use or natural geomorphic changes form the non-climatic drivers. Of these, the main climatic driver which control freshwater resources are the evaporation and precipitation. More intense extreme precipitation events are expected due to climate change (IPCC, 2012). Such drivers question the sustainability of resources by decreasing water supply or increasing demand (Cisneros et al., 2014). The future of freshwater systems will be hit strongly by demographic, socioeconomic, and technological changes, including lifestyle changes. The details of framework and linkages for considering impacts of climatic and social changes on freshwater systems, and consequent impacts on and risks for humans and freshwater ecosystems are provided in Figure 1.

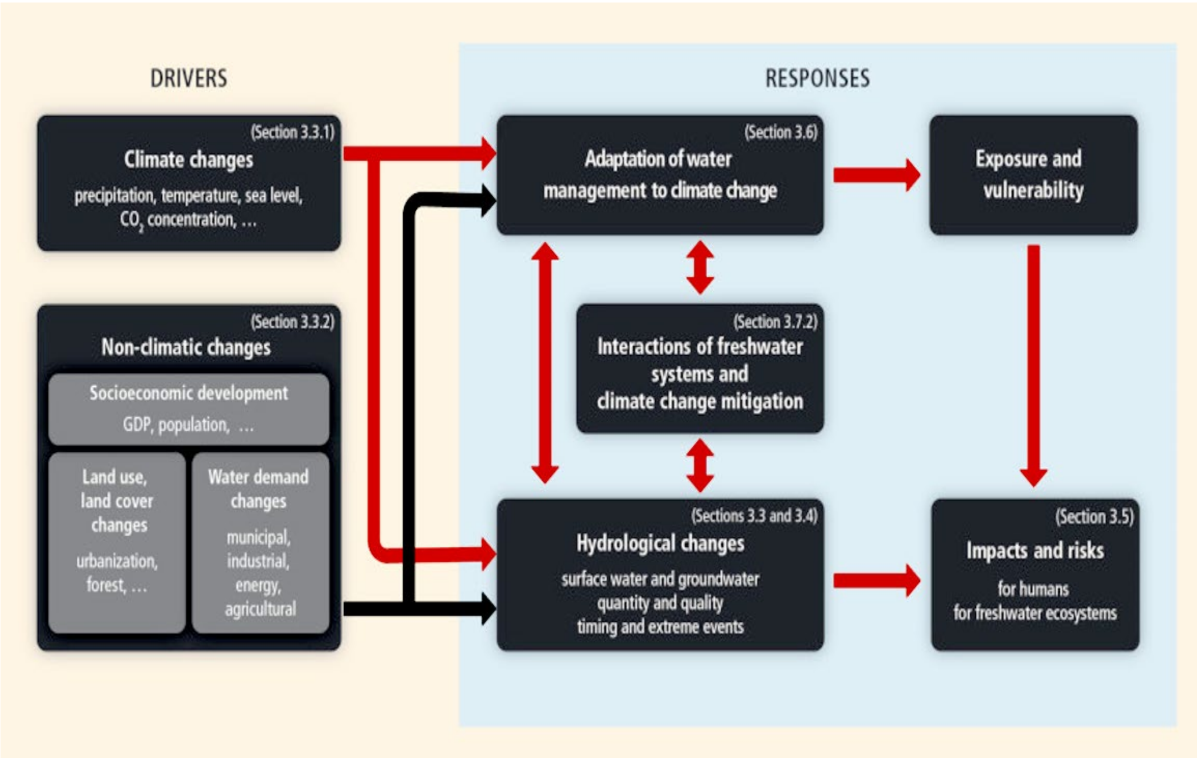

Figure 1. Framework (boxes) and linkages (arrows) for considering impacts of climatic and social changes on freshwater systems, and consequent impacts on and risks for humans and freshwater ecosystems (Source: IPCC report, 2007)

According to VanVuuren et al. (2012) socioeconomic features which include the social, economic, demographic as well as ecological conditions can also create climate changes. Changing land use pattern because of urbanization will also affect freshwater systems strongly. Ninety percent of global water is used for irrigation purpose which will make a severe impact on the freshwater availability to the humans and the ecosystems (Döll, 2009).

Complicated anthropogenic and natural systems working simultaneously influence climate change which affects the quality of water. Water quality projections depends upon climatic and environmental inference, local conditions and also the current state of pollution (Bonte and Zwolsman, 2010; Kundzewicz and Krysanova, 2010; Sahoo et al., 2010; Trolle et al., 2011). Intense effect of climate change includes alteration on hydrological cycle, dried up water resources and thereby its depletion, decline of water table level, saline water intrusion, water logging etc. which causes strain on the availability of drinking water and altered precipitation and unpredictable floods and droughts on inland freshwater wetlands.

The seasonal rainfall in India can be understood from groundwater recharge and the availability of water during summer. Because of increase in population and climate change, per capita availability of freshwater in major river basins is decreasing and degrading at a much faster pace and this will be experienced as water stress in most of the basins by 2030 (Nair, 2016). This will be followed by many serious socio-economic issues like disputes and raising price for water etc. Changes in monsoon patterns cause water stress, decrease in the availability of water in the lakes and rivers of Asia and Africa (IPCC, 2007) causing negative impacts on fish migration, spawning and seed availability for farmers which will also produce less water retention time in non-perennial water bodies (Goswami et al.,2006). In terms of fisheries, African countries are more vulnerable state due to the combined effects of predicted warming, the relative importance of fisheries to regional economy and nutrition coupled with limited societal capacity to adapt to potential impacts and opportunities. Besides, increasing number of extreme climatic events will have serious repercussions on the ecology and biodiversity of inland water bodies, besides the socio-economic losses.

IMPACT, VULNERABILITIES AND RISKS

The impacts of climate change on freshwater ecosystems is always complex, not fully understood and often beyond prediction. However, all these impacts will lead to changes in the quantity, quality, and timing of water. Changes will be driven by shifts in the volume, seasonality, and intensity of precipitation; alteration of surface runoff and ground water recharge patterns; changes in evapotranspiration; increased air and water temperatures; and rising sea levels and other extreme climatic events. In the tropical regions, all these together will lead to a number of key eco-hydrological impacts on freshwater ecosystems including increased low-flow episodes and water stress in some areas; shifts in timing and intensity of floods; increased evaporative losses, especially from shallow water bodies; saltwater intrusion in coastal, deltaic, and low-lying ecosystems, including coastal aquifers; more intense runoff events leading to increased sediment and pollution loads; and increased extremes of water temperatures (WWF, 2010). The possible impacts of climate change in aquatic ecosystems are discussed.

Hydrological cycle

Climate and water cycle are inseparably linked and every change in the climatic system induces a change in the water system, and vice versa. The climate change would impact precipitation, sea level, river flow, soil moisture, evapotranspiration, and ground water, thereby impacting the quantity and quality of freshwater availability (Kundzewicz, 2008). Several studies point towards the impact of climate-driven factors on the recent evolution of the water cycle at large scales (Bindoff et al., 2013), particularly on precipitation (Zhang et al., 2007) or evapotranspiration (Douville et al., 2012). The studies in India also indicate the possible implications of climate change on hydrological cycle (Mehrotra and Mehrotra, 1995), including the Western Ghats biodiversity hotspot (Ramachandra et al., 2013). This points to the research need to enhance the observation network (especially for hydro-meteorological variable such as precipitation, evaporation, snow melt, stream flow, runoff, infiltration) in order to get a quantified estimate of water balance in most of the river and lake basins in Asian and Africa.

Ecosystem Services and biodiversity

Climate change has severe projected substantial impacts on ecosystem services. The impacts happen via changes in the distribution and value of water over space and time. Such proposed effects will be different depending on the extent of the impact of such changes in the distribution of water and the adaptive capacity of the region's biophysical and social system (Chang and Bonnette, 2016). Overview of ecosystem services that are directly and indirectly impacted by climate change and local anthropogenic impacts is given in Figure 2. It show cases the complex, cyclical nature of how the use of ecosystem services can, through direct and indirect mechanisms, affect those same ecosystem services (Liu et al., 2015). Impacts of climate change on ecosystem services is an area not investigated by the research community in India, despite the fact that it is highly important in planning adaptation strategies.

Declines in river flows, increased drought and extreme flooding events, and salt-water intrusion are all very likely to result in changes to the composition, structure and function of freshwater ecosystems. In addition, existing stresses on freshwater ecosystems of Kerala (e.g. habitat degradation and alterations, habitat loss, altered hydrology, pollution, habitat loss, invasive species, etc) will be aggravated by climate change, increasing the risk of species extinctions and shifts in the provision of ecosystem services.

Biodiversity in backwaters is disappearing at a much faster pace as a consequence of developmental projects which promote vigorous use of resources and environment and also the ample reclamation of these water bodies result in irretrievable loss of habitat. These backwaters exert serious impact on the coastal fisheries as they serves as nursery and breeding grounds for a variety of coastal fish and shellfish species. Encroachment into diverse sections of water bodies including wetlands, paddy fields, lakes etc. are encroached upon in different parts of the state for constructing buildings, houses and resorts violating the laws (Nair, 2016).

The heavy rain and floods could impact the ecosystem and ecosystem services considerably. In the freshwater ecosystems along the Western Ghats, the impacts would be much more pronounced. Floods may trigger a major shift in the diversity of flora, with invasive species taking over from endemic varieties. The floods also aid in the escape of exotic fish species cultivated in the flood plains to the natural water bodies. It could enhance the threat to Rare, Endangered and Threatened (RET) species, leaving them more vulnerable.

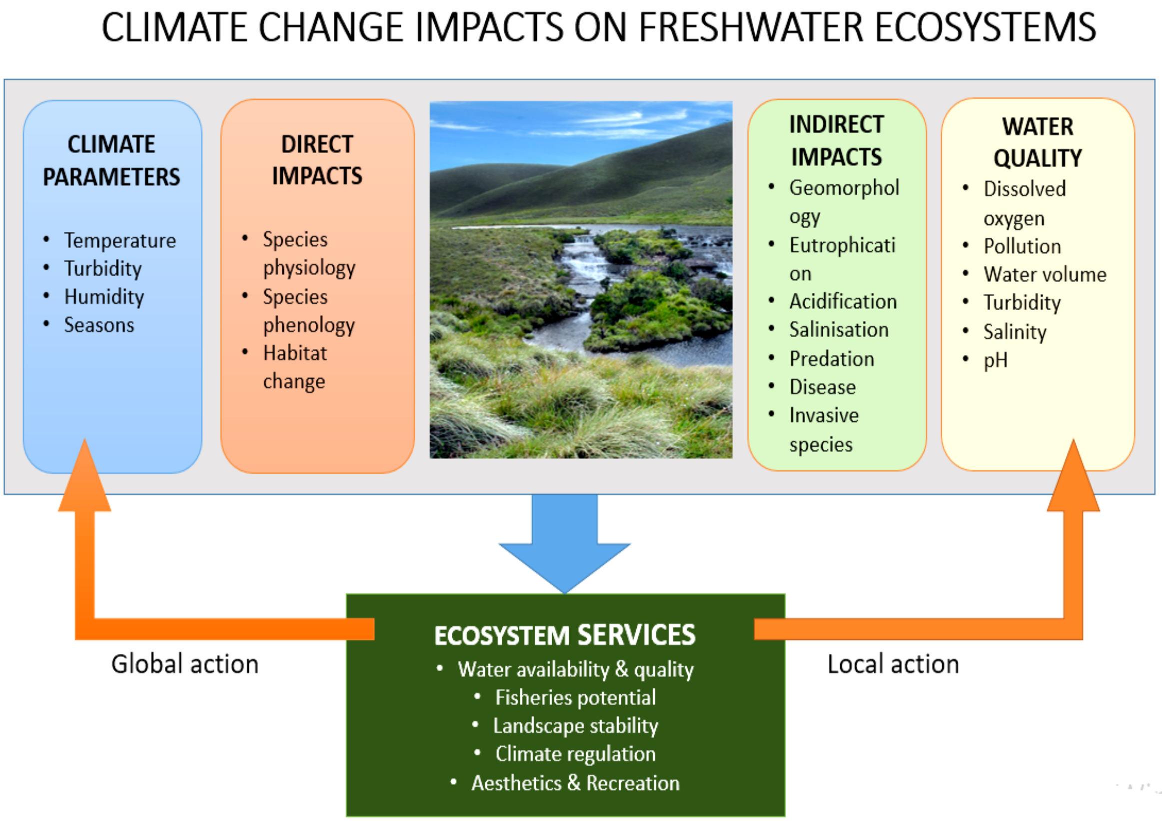

Figure 2. Overview of ecosystem services that are directly and indirectly impacted by climate change and local anthropogenic impacts (adapted from Liu et al., 2015).

Agriculture and animal husbandry

India is home to more than 16 per cent of the world population, at the same time harbours only 4 per cent of the world water resources. Agriculture is directly dependent on climate and water is a critical component of agricultural vulnerability in India where agricultural production depends on availability of rainwater and water available through irrigation. A warmer climate will accelerate the hydrologic cycle, altering rainfall, magnitude and timing of run-off. Warm air holds more moisture and it will result in an increase in evaporation of surface moisture. Climate change has a direct impact on crop evapotranspiration, thereby affecting the soil moisture, groundwater recharge, and frequency of flood or drought, and finally groundwater level in different areas. The observed and predicted vagaries of monsoon and the climate driven changes in soil quality would ultimately impact regional agriculture. The multiple impacts of climate change on agriculture are summarised in Figure 3. The earlier-anticipated potential benefits of climate change from carbon dioxide would be offset by pollution, serious related climate effects as well as nutrition limitation.

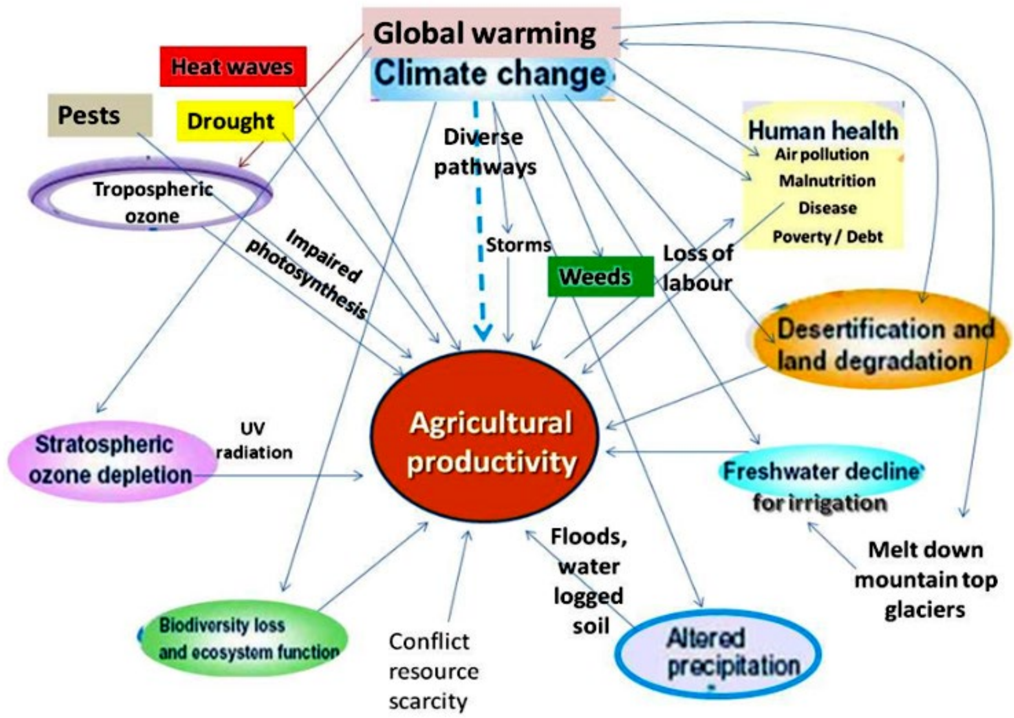

Figure 3. Schematic representation of multiple impacts of climate change on agriculture

Dev (2011) pointed out that agriculture was less sustainable in the past because of less yields, soil erosion and natural calamities, water and land related problems which made the rural livelihoods susceptible to climate change vulnerability. In addition, rise in sea level will increase the risk of permanent or seasonal saline intrusion into ground water and rivers which will have an impact on quality of water and the agricultural productivity, particularly in below-sea level farming systems in various regions of the world.

Due to deforestation and increase in sea surface temperature, the temperature across the high ranges and low lands have increased considerably (Rao, 2017). Vagaries in monsoon may impact the production of economically valuable crops like pepper, coffee, tea, cardamom, banana, ginger and tuber crops. By 2050, the food production is supposed to increase by 60 per cent to meet the increase in demand and therefore any substantial changes in climate would ultimately impact local agricultural productivity (Alexandratos and Bruinsma,2012) and livelihood. Wayanad district experiences low water yield and increasing water stress because of decrease in precipitation and increase in temperature and evapotranspiration due to climate change which is supposed to affect the crops in the district causing reduction in yields and changes in cropping patterns (Dinesan, 2017).

Climate change poses formidable challenge to the development of livestock sector in India. Livestock production will be limited by climate variability as animal water consumption is expected to increase by a factor of three, demand for agricultural lands increase due to need for 70% growth in production, and food security concern since about one-third of the global cereal harvest is used for livestock feed (Rojas-Downing et al., 2017).

According to Sirohi and Michaelowa (2007), "the anticipated rise in temperature between 2.3 and 4.8°C over the entire country together with increased precipitation resulting from climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their productive and reproductive performance, and hence reducing the total area where high yielding dairy cattle can be economically reared. Given the vulnerability of India to rise in sea level, the impact of increased intensity of extreme events on the livestock sector would be large and devastating for the low-income rural areas. The predicted negative impact of climate change on Indian agriculture would also adversely affect livestock production by aggravating the feed and fodder shortages". The locally adapted indigenous breeds in India therefore would play a critical role in future towards climate change adaptation.

Impacts on Wetlands

Wetlands including swamps, mangroves, lakes and marshes play an important role in carbon cycle. While wetland sediments are the long-term stores of carbon, short-term stores are in wetland existing biomass and dissolved components in the surface and groundwater (Wylynko, 1999). Though wetlands contribute about 40 per cent of the global methane (CH_4) emissions, they have the highest carbon (C) density among terrestrial ecosystems and relatively greater capacities to sequester additional carbon dioxide (CO_2) (Pant et al., 2003).

In India, coastal wetlands are playing a major role in carbon sequestration. The total extent of coastal ecosystems (including mangroves) in India is around 43,000 km^2 (Kathiresan and Thakur, 2008). Overall, mangroves are able to sequester about 1.5 metric tonne of carbon per hectare per year, and the upper layers of mangrove sediments have high carbon content, with conservative estimates indicating the levels of 10% (Kathiresan and Thakur, 2008).

Limited analysis on the impact of climate change on wetlands in India suggests that high altitude wetlands and coastal wetlands (including mangroves and coral reefs) are some of the most sensitive classes that will be affected by climate change (Patel et al., 2009). In case of the coastal wetlands such as Indian part of Sundarbans mangrove, rising sea surface temperature and sea level rise due to thermal expansion, could affect the fish distribution and lead to the destruction of significant portion of mangrove ecosystem. Further destruction of the Sundarbans mangroves would diminish their critical role as natural buffers against tropical cyclones resulting in loss of lives and livelihoods (UNESCO, 2007; CSE, 2012).

Climate change induced rising temperature and declining rainfall pattern presents a potential danger to the already disappearing lakes in the Gangetic plains (Sinha, 2011). Decreased precipitation will exacerbate problems associated with already growing demands for water and hence alter the freshwater inflows to wetland ecosystems (Bates et al., 2008; Erwin, 2009), whereas, rise in temperature can aggravate the problem of eutrophication, leading to algal blooms, fish kills, and dead zones in the surface water (Gopal et al., 2010). Also, seasonality of runoff in river basins such as Ganges will increase along with global warming, that is, wet seasons will become wetter and dry seasons will become drier (World Bank, 2012). This would have severe adverse impact on affected populations, especially if the seasonality of runoff change would be out of phase with that of demand.

Impacts on fisheries and aquaculture

Climate change may affect the hydrology and fisheries of inland waters through increased precipitation, air temperature, and decrease in water quality. The health and productivity of the ecosystems depend upon the fisheries which they are based and are vulnerable to physical and chemical changes in temperature, salinity, acidity and water levels and flows (IPCC, 2007; Bindoff et al., 2018). Climate change impact pathways in fisheries and aquaculture are detailed in Fig. 3. The recent report of Food and Agriculture Organization (FAO) indicate that climate change will affect the productivity of the world's freshwater and marine fisheries, and the impacts on inland sector will be connected to the scarcity and quality of water of natural water bodies. In the aquaculture sector, the short-term climate change can include losses of production and infrastructure arising from extreme events such as floods, increased risks of diseases, parasites and harmful algal blooms, and the long-term impacts can include reduced availability of wild seed as well as reduced precipitation leading to increasing competition for freshwater (Barange et al., 2018).

Fisheries in lakes, rivers, dams and wetlands are affected by changes in rainfall and run-off, rise in temperature, drought, evaporation, intense storms, river flow and several other hydrological parameters which results in water level variations, habitat loss, disease and mortality, alteration of productivity, invasive alien species and species loss. Fisheries and aquaculture too contribute to climate change by altering mangroves and coastal wetland ecosystems, and also consume energy required for the production of processed feeds and also to pump water.

The outcome of extreme weather events and changes in monsoon pattern storms and floods are huge losses in cage culture systems in rivers and lakes causing large fin fishes to escape (Soto et al., 2001).Rise in temperature generated by humans on lakes and rivers cause grave threats to various fish species and fish culture production (Cheung et al., 2010; Fickeet al., 2007) as recognised by the report of Intergovernmental Panel on Climate Change (IPCC 2007). According to Katikiro and Macusi (2012) and Xenopoulos et al. (2005) inland fisheries which are artisanal fisheries will be extremely affected by changing water levels and increasing occurrence of dry spells as well as flooding. Climate change also causes increase in vaporization, turbidity, reduced solar radiation reaching water bodies resulting in plankton blooms leading to water pollution, run-off due to flooding creating damages to cages and loss of livelihood of fish farmers (Anyanwu et al., 2014). Rise in temperature due to climate change cause stress in fish and cause diseases.

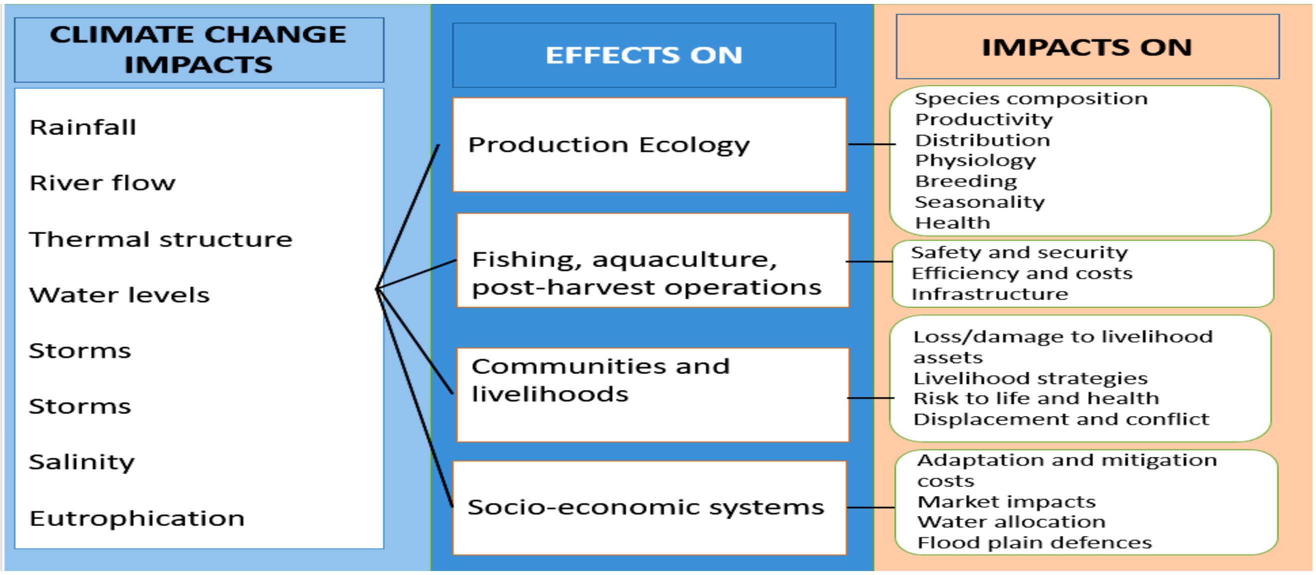

Figure 3. Climate change impact pathways in fisheries and aquaculture (adapted from Badjeck et al., 2010)

Human health

In addition to threats to water supplies for drinking and hygiene, the extent of mosquito-borne diseases may expand due to the impacts of fewer but heavier rainfall events on mosquito breeding. Projected changes to surface water hydrology may also lead to more frequent and prolonged toxic algae blooms. Reports indicate that in India climate change poses serious threat to public health from extreme weather-related disasters to wider spread of such vector-borne diseases as malaria and dengue (Majra and Gur, 2009). Higher temperature and contaminated water would trigger disease outbreaks and spread of pathogens. Vaccine preventable Japanese encephalitis epidemic due to rainfall has been reported from Himalayan region by Partridge et al. (2007) and Bhattachan et al. (2009) and to rainfall and temperature in South and East Asia (Bi et al., 2007; Murty et al., 2010). Similarly, Devi and Jauhari (2006), Dev and Dash (2007), Dahal, (2008) and Laneri et al. (2010) showed correlations of frequent occurrence of malaria with rainfall which otherwise is influenced by non-climatic variables. Increases in heavy rain and temperature will raise the risk of diarrheal diseases, dengue fever and malaria (IPCC, 2014).

Research linking temperature and health effects in tropical countries is sparse. However, understanding of the current impact of weather and climate variability on population health is the first step for assessing the effects of temperature, rainfall, infectious diseases and extreme weather.

Socio-economic and other impacts

Responding to the growing imbalance between water supply and demand has driven changes in water governance, in particular water allocation, in many parts of the world. With a growing population and people living under water stress, particularly for drinking water, there is also likely to be further pressure on individuals and organisations to alter their water use patterns and accept significant changes to the quality and quantity of water provided for different purposes. Policy, infrastructure and social changes are likely to be necessary to facilitate adaptation to water scarcity in both rural and urban areas. Further, there will be more demands for more desalination plants and recycling and reuse of water from the effluents (IPCC, 2012).

Changes in the structure and function of rivers, estuaries and wetlands will affect the ecosystem services they provide, with far-reaching social and economic implications. For example, in rural areas, declines in agricultural productivity and shifts in farming are very likely. Moreover, salt-water intrusion into estuaries and wetlands may affect coastal fisheries and tourism. Water related conflicts may occur regionally due to higher demands for water and scarcity.

ADAPTATION, MITIGATION AND MANAGEMENT

Protection of biological diversity of aquatic ecosystems and integrity are important activities to improve the resiliency of aquatic ecosystems so that they continue to provide important services under changed climatic conditions. Appropriate adaptation and mitigation strategies would bring community empowerment in the face of climate change vulnerability.

Global warming, rapid urbanization, industrialization and economic development are the key factors which cause stress and will intensify climate change (reference??). Attention among policy-makers is divided about how to minimize the change, how to mitigate its effects, how to maintain the aquatic ecosystems and biodiversity on which societies depend and how to adapt human societies to the changes. Maintenance and rehabilitation of ecological integrity of the aquatic ecosystems will inevitably include restoration of health of the ecosystems and the biological resources, not to speak of sustainability of ecosystem services.

The ecosystems in good health may remain in few protected areas in Kerala, through a long tradition of conservation management that is largely species-based, as amenable to adaptive management. In many cases it may be perceived as the richness of plant and vertebrate communities and this often forms a focus for planning. The need of the hour is preparation of a data base on impacts of climate change on each specific kind of aquatic ecosystem and prioritize its management.

In the case of freshwater biodiversity, adaptation strategies that maintain well-functioning ecosystems are pivotal. This is achieved through enhancing resilience, removing or managing existing stressors, and maintaining diverse and well-connected mosaics of ecosystems (i.e. aquatic, riparian and terrestrial components) across the landscape. Surface and groundwater resources are essential to freshwater biodiversity and aquatic ecosystem processes. Appropriate management is critical. Over-allocation of water resources represents a major obstacle to implementing suitable adaptation strategies for protecting freshwater biodiversity.

Mitigation measures include efforts to develop integrated water management strategies along with water saving technologies, increasing water productivity and water reuse to adapt to climate change (IPCC, 2014). However, most of these efforts in developing countries are land-based and therefore fresh efforts are required for mitigating impacts of climate change. Negative repercussion arises in natural ecosystems and carbon sequestration when we prevent nature to take its own course to changing conditions as we build sea walls, channels, bunds and dams for agriculture and human settlement (IPCC, 2014). The freshwater areas under protected area network are comparatively less in tropical countries and there is an urgent need to conserve highly threatened ecosystems, especially all the remaining mangrove ecosystems. Further, the afforestation initiatives in the ecologically sensitive areas along with integrated watershed management programmes will go a long way in adaptation process. Beyond the intrinsic value of wild species and ecosystems, ecosystem-based approaches to adaptation aim to use the resilience of natural systems to buffer human systems against climate change, with potential social, economic, and cultural co-benefits for local communities (IPCC, 2014).

Various downscaled tools to support, formulate, and implement climate change adaptation policy for local governments are under development. One of the major tools is vulnerability assessment and policy option identification with Geographical Information Systems (GIS). These tools are expected to be of assistance in assessing ecosystem based adaptation options by examining estimated impacts and identified vulnerability for aquatic ecosystems.

While top-down approaches provide scientific knowledge to local actors, community-based approaches are built on existing knowledge and expertise to strengthen coping and adaptive capacity by involving local actors (van Aalst et al., 2008). At the same time community-based approaches may have a limitation in that they place greater responsibility on the shoulders of local people without necessarily increasing their capacity proportionately (Allen, 2006). More community reserves and community-managed watersheds and ecosystems would not only ensure sustainability, but also provide avenues for adaptation for the stake holders.

In the fisheries sector, some of the impacts of climate change are likely to be positive. For example, increased precipitation could reduce current water stress in some regions and also lead to the expansion of habitats available to fish, leading to higher abundances and potential yields. Taking advantage of new opportunities could require investment in infrastructure and equipment, for which external support may be required. In cases of both new opportunities and negative impacts, a key requirement for nearly all countries and regions will be to ensure flexibility (within the limits of sustainable use) in policies, laws and regulations. This flexibility will then allow fishers to switch between target species and adjust their fishing practices in response to changes in the ecosystems they utilize for fishing. Adaptation in post harvest processes will also be important through, for example, the development or improvement of storage and processing equipment. The implemented post harvest processes can increase the capacity and implementation of robust biosecurity systems in order to ensure the quality of fish and fish products through to the consumers, as well as facilitating possible access to higher value markets (Barange et al., 2018).

The options for adaptation and building resilience in aquaculture should be applied in accordance with an ecosystem approach to aquaculture. They include: (i) improved management of farms and choice of farmed species; (ii) improved spatial planning of farms that takes climate-related risks into account; and (iii) improved environmental monitoring involving users. Alternate livelihood options should be provided to the fishermen to adapt to the changing climate scenarios.

In addition to emissions reductions from the fisheries and aquaculture sector, there is the potential to store carbon in some coastal ecosystems such as mangroves, sea weed ecosystems, sea grass beds, etc. These ecosystems have the potential to remove and store atmospheric carbon at much greater rates than terrestrial ecosystems (McLeod et al., 2011). Some of these systems, such as mangroves also provide additional benefits to communities through flood control, buffering coastlines from storms, water quality, and provide habitat for juvenile fish. Therefore, adaptation may address issues not specifically focused on fisheries or aquaculture, such as mangrove restoration for the primary purpose of buffering coastal communities from storm surge and coastal erosion (Shelton, 2014).

In short, ecosystem-based adaptation recognizes the critical nature of the services that biodiversity and ecosystems provide to human communities and that help build resilience to climate change. Incorporating ecosystem-based adaptation into an integrated approach to climate change adaptation can provide longer term, more effective and more cost efficient solutions that support human well-being and a healthy environment. This approach is particularly relevant to the inland water bodies due to the complex and dynamic nature of these systems.

KNOWLEDGE GAP

Climate change research is at its infancy in the state, and one of the major handicap in arriving at better conclusions on the impact is the lack of data over a time scale with regard to the inland ecosystems. Sustain and expand existing monitoring networks and data collection on hydrologic and meteorological conditions and water demand is one of the priority areas. Similarly there is a need for stronger data on precipitation and river discharge systematically, and management of water flow from dams. A comprehensive bio-monitoring network with clearly defined goals for the State is necessary to fill the gaps in climate change. Long-term climate change monitoring datasets are vital and often useful for research on climate change and the information must be shared across the regions. Due importance should be given to research with improvised models and other methods to explore and foretell the interactions between climate change, invasive species, habitat fragmentation and ecosystem dynamics and also to identify the stressors and threats which will create an impact on climate change.

Urgent actions need to be executed at the local (community involvement), regional and national level and for short and long term involving a multi-disciplinary team. Information on significant variables like soil moisture, groundwater depth, water quality, water demand (including water budget of aquatic ecosystems), rates of surface water and groundwater withdrawal by each sector, long-range diversions etc. are particularly limited in India which result in limited assessment capability.

Engaging stakeholders will definitely leads to the success of the programme and proper public awareness should be propagated regarding environmental and health issues. Further, ecosystem based conservation plans involving local communities is yet another priority programme to be implemented, together with declaration of more protected areas including fish sanctuaries, which may serve as 'climate refugia'.

In many Asian and African countries where tourism is projected as a source for improving economic benefits, maintenance of inland aquatic ecosystems in good health and promotion of responsible tourism would help in sustainable management in the era of climate change. Carbon sequestration capacity of the countries should be increased by promoting public transportation, replacement of old machinery with new energy efficient ones, afforestation, reduction of CO_2 emission from households etc. Another challenge is to increase the food productivity using low emission pathway to reduce the impact of climate change.

Since fisheries is considered as a major source of food while policy formulation, fisheries should come to the forefront but the benefits gained from the sector are often ignored and continue to lack sufficient attention by decision makers in both adaptation to climate change and food security policy formulation. It is also endorsed upon that to minimize the impacts of climate change on fisheries and also to increase the flexibility of the farmers, investments are needed for sustainable artisanal fisheries and market infrastructure to tackle post- harvest losses and also to provide economic incentives. Top priority should be given for the conservation of existing wetlands and restoration of all freshwater bodies should be undertaken as a major measure to fight against climate change. Also science and policy should communicate and interact together to pursue climate change.

More studies with state-specific scientific or modelling studies on climate change are needed, especially in a tropical countries, to study the impacts for effective adaptation strategies and policy framework for the region. Inland fisheries sector has to be boosted by adapting a suitable technology which is eco-friendly and less hostile. Moreover, while taking policy formulations, fisheries and aquaculture sectors need to be directly linked to food security and employment of the rural population.

To enhance the development of young professionals in the field of climate change adaptation, the topic could be included in higher education, especially in formal education programs. Shaw et al. (2011) mentioned that higher education in adaptation and disaster risk reduction in the Asia-Pacific region can be done through environment disaster linkage, focus on hydro-meteorological disasters, and emphasizing synergy issues between adaptation and risk reduction.

Overall, it may be noted that the climate change impacts on inland aquatic ecosystems, though very important in ensuring food security and ecosystem services, they have not received considerable attention by the researchers, planners, policy makers and practitioners. This warrants a critical review of existing management plans for watershed conservation, flood mitigation, environment and biodiversity regulations, covering potential implications of climate change in regional perspective, besides following an ecosystem approach in conservation and mitigation.

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Public health implications of bovine Cysticercosis from cattle slaughtered at Dilla municipal abattoir, Southern Ethiopia

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KEYWORDS:

Active abattoir survey;

Cysticercus bovis;

Dilla town;

Taeniasis;

Questionnaire survey

Research article

ABSTRACT

A cross sectional study was conducted during November 2013 to June 2014 to estimate the prevalence of Cysticercosis from abattoir survey and Taeniasis within the society found in and around Dilla town. Active abattoir survey and questionnaire survey were performed to accomplish the study. Of the total of 400 inspected cattle carcasses, 17 had varying number of *C. bovis* giving an overall prevalence of 4.25% (17/400). Anatomical distribution of the cyst showed that highest proportions of *C. bovis* cyst were observed in shoulder muscle and tongue (29.41%), followed by, masseter muscle (23.53%), heart (11.76%) and liver (5.88%). Of the total 69 interviewed respondents, 57.79% (40/69) had contracted *T.saginata* infection. The majority of the respondent had an experience of raw meat consumption (65.29%, 45/69) as a result of traditional and cultural practice. From those raw meat consumers, 62.2% (28/45) were experienced taeniasis. However, no significant association was observed between raw meat consumption and taeniasis ($p<0.05$). The findings of this study including prevalence of *C. bovis* and questionnaire survey of taeniasis prevalence indicated the importance of Cysticercosis and Taeniasis in public health aspects. Therefore, due attention should be given to the public awareness and strict routine meat inspection in order to safe guard the public health.

INTRODUCTION

Bovine cysticercosis is a cystic stage of *Taenia saginata*, zoonotic parasite with its significant impact on human health. The cystic stage usually affects the muscle of cattle where humans are susceptible from the contaminated raw meat (Taylor et al., 2007). Taenia infection in human is referred to as Taeniasis and the one caused by the larval stage is referred to be cysticercosis (Hancock et al., 1989). Bovine cysticercosis, caused by the metacestodes of *T. saginata*, is distributed worldwide occurring in developed as well as developing countries (Dorny et al., 2009). However, the prevalence of this parasite is considered to be higher in developing countries. This phenomenon is related to poor sanitation, traditional cattle husbandry systems and inadequate meat inspection facilities (Cabaret et al., 2002; Dorny and Praet, 2007).The life cycle and transmission of parasite occurs most commonly in environments characterized by poor sanitation, primitive livestock husbandry practices and inadequate meat inspection, management and control policies (Mann, 1983; Phiri et al., 2003). Humans are the obligate final host and become infected by ingesting infected meat that has been inadequately cooked or frozen (Scandrett et al., 2009). Most incidents arise in cattle as a result of direct exposure to proglottids shed

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from humans, but there have been some reports of large scale outbreaks resulting from sewage-contaminated feed or forage. Even in developed countries where high standard of abattoir meat inspection that identify measly from beef carcass, did not succeeded in eliminating this parasites (Frolova, 1982; Smith, 1994).

Generally cysticercosis in animals is expected to have insignificant clinical effect. Nevertheless, it is economically important as it causes carcass condemnation arising from heavy infestation with the cysticerci of *T. saginata*. Additionally, there is cost related to inspecting meat, the necessity to freeze or boil infected meat and losses may also occur from restriction in exportation of live animal and their products (Soulsby, 1982). Cysticercosis was significantly more prevalent in between man and animal and the use of causal workers in feedlots may be factors that are conducive to *Taenia saginata* transmission (Dorny et al., 2002). In previous studies, taeniasis or bovine cysticercosis is an important meat-borne zoonosis with the impact on the safety of food presented for human consumption in different parts of the country. The reported prevalence of taeniasis in the human population has been found to range from 31.0% to 89.4% in Ethiopia (Tembo, 2001; Abunna et al., 2008; Megersa et al., 2010; Bedu et al.,2011; Endris and Negussie, 2011). In Ethiopia, the prevalence of bovine cysticercosis ranges from 3.1 % in the central part to 26.25% in the southern part of the country (Tembo, 2001; Dawit, 2004; Nigatu, 2004; Hailu, 2005; Abunna et al., 2008). High prevalence of cysticercosis is related to the tradition of eating raw beef which is considered one of a major risk factor for its transmission (Mamo, 1988). However, there is limitation in terms of countrywide study on prevalence of bovine cysticericosis. Although there were some research works carried out with associated factors, there is still little information regarding the recent status of bovine cysticercosis and the prevalence of *T. saginata* in humans in areas like Dilla and its surroundings. Therefore, the objective of this study was to estimate the prevalence of cysticercosis in animals and taeniasis in human.

MATERIALS AND METHODS

Description of the Study Area

Dilla town is currently functioning as an administrative center of the Gedeo Zone in the Southern Nations Nationalities and Peoples Region (SNNPR) in Ethiopia Geographically, Dilla town is located on 6°24′30″N Longitude and 38°18′30″E Latitude with an average elevation of 1570 meters above sea level. Comparatively, the town is located 90 Kms from Hawassa, the capital of SNNPR and 359 Kms on the main road from Addis Ababa to Nairobi. Dilla is one of the main market centers in Southern Ethiopia and it is one of the fastest growing urban centers in the country. Based on the 2007 population and housing survey of Ethiopia, the population of Dilla town was estimated to be about 59,150. Livestock population of the town was estimated to be 12, 475. The town is covering a total land area of about 1123.4 hectare. The mean atmospheric temperature of the town varies from 20°C in summer to 28°Cin winter and the average rain fall is 1257.2mm (CSA, 2008).

Study Animals

Animals which were presented to Dilla municipal abattoir mainly come from Dilla and the surrounding area (Wonago, Kura, Bore, Sonkicha, Tunticha and Kibre Mengist). Local zebu cattle and cross breed presented to abattoir for slaughter were used as a study population for active abattoir survey.

Study Type and Sample size

A cross-sectional study was carried out from November 2013 to June 2014. By following a systematic random sampling method, a total of 400 cattle were randomly sampled and routinely inspected for the presence of *T. saginata* metacestodes in edible parts of the slaughtered cattle. The total number of cattle required for the study was calculated based on the formula given by Thrusfield (2005) for a simple random sampling method. By rule of thumb where there is no information for an area it is possible to take 50% of expected prevalence. Using 5% degree of absolute precision, 384 animals need to be sampled but, 400 animals were sampled.

Study Methodology

Active Abattoir Survey: Active abattoir survey was conducted during routine meat inspection on systematically selected 400 cattle slaughtered at the abattoir. Ante-mortem and post-mortem examinations were conducted by visiting the abattoir three days a week**.** During ante-mortem examination, each study animal was given an identification number and its sex, age and origin was recorded. This is to avoid the unnecessary mixing with organs during inspection. Age estimation was done based on owner information and dentition. During inspection, each predilection sites were inspected according to the guideline of Ministry of Agriculture (1972).

Questionnaire Survey: A semi-structured questionnaire was administered to 69 volunteer respondents from Dilla city. In the questionnaire survey, usage of toilet, and raw meat consumption habit were addressed.

Data Management and Analysis

Abattoir data was collected and recorded and the data was carefully entered into Microsoft excel. The outcome variable for the abattoir study were cases *Cysticercus bovis* detected during routine post mortem inspection at Dilla municipal abattoir. Logistic regression was employed to analyze the association of the occurrence with the potential risk factors like sex, origin, breed, age, and body score condition using STATA statistical software version 11**.** Multivariate analysis for the risk factors of active abattoir and questionnaire survey during study period was used in which the degree of associations among risk factors was indicated with Odds ratio.

RESULTS

Abattoir Survey

Prevalence: Of the total 400 cattle inspected; 17 cattle were positive for bovine cysticercosis with the prevalence of 4.25. Among different risk factors, the proportion of *Cysticercus bovis* was higher in cross-bred (4.34%), medium BCS (4.33%), >9 years old (6.93%), female (9.43%) cattle originated from Kibre-Mengist (13.3%) places (Table 1).

Table-1: Proportions of cysts occurrence in inspected organs and carcass at Dilla municipal abattoir during the study period(n=400)

Variable		Examined animals	Positive animals	Proportions
Breed	Local	377	16	4.24
	Cross	23	1	4.34
BCS	Medium	346	15	4.33
	Good	54	2	3.70
Age	3 - 5 year	89	2	2.25
	5 - 9 year	210	8	3.81
	>9 year	54	7	6.93
Sex	Male	347	12	3.46
	Female	53	5	9.43
Origin	Wonago	306	11	3.59
	Dilla	23	0	0
	Kura	4	0	0
	Sonkicha	18	1	5.56
	K.meng.	15	2	13.3
	Bore	16	2	12..5
	Tunticha	18	1	5.56

Anatomical Distribution of Cysts: Analysis of active abattoir survey showed that there was a variation in the infected anatomical distribution of cysticerci in organs inspected. Of the organs examined, the highest proportion of *C. bovis* cysts were observed in the tongue (29.41%) and shoulder muscle (29.41%) followed by masseter muscles (23.53%), heart (11.76%) and liver (5.88%) (Table 2).

Table-2: Frequency of anatomical distribution of *C.bovis* (n=400)

Organs affected	Total number of affected organs	Prevalence	Proportion within organs
Tongue	5	1.25	29.41
Shoulder muscle	5	1.25	29.41
Masseter muscle	4	1	23.53
Heart	2	0.5	11.76
Liver	1	0.25	5.88
Total	**17**	**4.25**	**100**

Questionnaire survey: Of the total 69 interviewed respondents who participated in this study, 57.97% (40/69) had contracted *T. saginata* infection. Proportion among different factors of respondents were analyzed and showed higher proportion in male (39.13%), >34 years (36.23%), and in those who consume raw meat (40.6%). Further analysis showed no significant difference between most of the risk factors (sex, age, meat consumption habit, residence and toilet usage) (P>0.05). However, respondents with college level showed less proportion (5.8%) compared to illiterate (15.94%) with a slight significance difference (p<0.05) (Table 3).

Table 3- Proportion of Taeniasis among the interviewed respondents in Dilla city, Southern Ethiopia (n=69)

Variables		No of interview (Infected)	Proportion	Odds Ratio (95% CI)	P-value
Sex	Female	25 (13)	52	1	
	Male	44 (27)	61.36	1.5 (0.46, 5.1)	0.485
Age	16 - 25	16 (7)	43.75	1	
	25 - 34	14 (8)	57.14	2.1 (0.35, 13.1)	0.409
	>34	39 (25)	64.10	2.9 (0.51, 16.52)	0.228
Education level	Illiterate	18 (11)	61.11	1	
	Primary	21 (14)	66.70	1.1 (0.21, 5.33)	0.939
	Secondary	18 (11)	61.11	2 (0.27, 15.16)	0.488
	College	12 (4)	33.33	10.47	0.052
Consumption	Cooked	24 (12)	50	1	
habit	Raw	45 (28)	62.20	1.5 (0.49, 4.64)	0.473
Residence	Rural	30 (17)	56.70	1	
	Urban	39 (23)	58.97	4.1 (0.7, 24.24)	0.117
Toilet usage	No	3 (2)	66.67	1	
	Yes	66 (38)	57.58	1.03 (0.07, 14.36)	0.983
Total		**69 (40)**	**57.97**		

DISCUSSION

The prevalence of *C. bovis* among the carcasses inspected at Dilla municipal abattoir was 4.25% which is in agreement with the findings of Tamirat et al. (2018) (4.2%) at Bahir Dar, Ibrahim and Zerihun (2012) (3.6%) at Addis Ababa abattoir, Taresa et al.(2011) (3.65%) at Jimma, Dawit (2004) (4.9%) at Gondar, Megersa et al. (2010) (4.4%) at Jimma and Bedu et al. (2011) (3%) at Zeway. However, higher prevalence of *C.bovis* were registered by Tegegne et al. (2018) (8.97%) in Kombolcha, Moje et al. (2014) (10.1%)at Shashamanne; Abunna et al. (2008) (26.25%) at Hawassa; Kebede et al. (2009) (7.5%) and Regassa et al. (2009) (11.3%) both at Wolaita Soddo abattoirs. The observed difference among these studies could be explained with the agro-climatic conditions of the study areas, the number of incision made during inspection, the ability of the meat inspector to identify the *C.bovis*, habit or culture of raw meat consumption, sample size and sampling method, level of environmental contamination with the eggs of *T. saginata*, dose and viability of egg consumed (Scandrett et al., 2009). Low infection among the inspected animals in the present study area could be due to limited number of incisions made on the predilections sites. This may in turn lead to missing of infected animals as the sensitivity of detecting the parasite will decline with limited number of incisions (Wanzala et al., 2003). The presence and number of cysts in any given site varied greatly among animals and demonstrate the absence of any true predilection sites for *C. bovis* (Scandrett et al., 2009). The present study

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showed that tongue and shoulder muscle, Masseter, heart, and liver were the muscle, predilection sites for the cysts of *C. bovis* which is similar to the results of Megerssa et al. (2010).

Regarding the anatomical distribution of the cysts, many researchers come up with different results like Abunna et al.(2008) and Getachew (1990) reported triceps as being frequently affected by the cyst, while Mulugeta (1997) found as heart as a preferable organ. However, the present study showed that the most frequently affected organ with the highest number of cysts was the tongue which is in agreement with different studies conducted in different parts of the country (Hailu, 2005; Bedu et al., 2011).

Human taeniasis was a widespread health problem in the study area with the prevalence of 57.79% and agrees with the findings of others, 64.2% by Taylor et al.(2007), 51.1% by Regassa et al.(2008), 56.7% by Bedu et al. (2011). However, it was higher than the report from Kombolcha (31%) (Endris and Negussie, 2011). In the current study, significant association were detected between different level of educational level in which respondents with college education showed lower level of taeniasis compared to illiterate ($p<0.05$). However, the rest of respondents factor including raw meat consumption showed no significant association with taeniasis ($p>0.05$). This contradicted with different researches that got association between raw meat consumption with taeniasis (Abunna et al., 2008; Megersa et al., 2010; Bedu et al., 2011; Endris and Negussie, 2011).

CONCLUSION & RECOMMENDATION

The recorded prevalence of bovine cysticercosis indicated the importance of this disease in the study area. The finding of this work demonstrates the importance of *Taenia saginata* (taeniasis) and *Cysticercus bovis* in human and animals respectively. The recorded prevalence of cysticercosis was found to be lower as compared to previous findings from different parts of the country. In the study area, the introduction of urban and rural health extension programs that taught the people intensively to use latrine might have a significant role for the reduction of *Cysticercus bovis* prevalence. According to selected respondents, higher proportion of respondents showed infection (taeniasis) at least once in their lifetime. In general, the findings of the present study reflects the circulation of cysticercosis and taeniasis in cattle and human, respectively which deserves serious attention by the various stakeholders in order to safe guard the public health. In this regard different intervention mechanisms like strict meat inspection procedures not to miss the cystic parasite and public education to create awareness on its transmission methods should be implemented.

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Distribution of Aeromonas bacterial population in water, sediment and Nile tilapia in fish culture pond, Guder, Ethiopia

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ABSTRACT

Assessing heterotrophic bacterial population in water, sediment and fish tissue assumes importance in predicting quality of the fish and water quality in culture system. The present study aimed to estimate the total heterotrophic bacterial population in water, sediment, and Nile tilapia (*Oreochromis niloticus)* cultured in an aquaculture farm at Guder Campus, Ambo University, Ethiopia. Water, sediment and fish body tissue were collected from the fish rearing pond, and were estimated for total heterotrophic bacterial population. Various physico-chemical characteristics were recorded following standard methods. The level of bacterial population in water, sediment and fish tissue were done by following standard methods and expressed as colony forming units (CFU) in water per milliliter (CFU ml^{-1}), sediment and fish tissues(CFU g^{-1}).The results revealed more bacterial population in sediment (3.43 $x10^6$ to 5.54 x 10^6 CFU g^{-1}) than in water (1.45$x10^6$ to 4.0$x10^6$ CFU ml^{-1}) and fish tissues (1.06 ± 1.10$x10^4$ to 1.74 ± 10.8$x10^4$ CFU g^{-1}in gill filaments; 1.62 ± 11.2$x10^4$ to 2.82 ± 13.0$x10^4$ CFU g^{-1} in intestine from; and 0.82 ± 5.9$x10^4$ to 1.60 ± 12.1.6$x10^4$ CFU g^{-1}; in kidney from 0.48 ± 5.0 to 0.77 ± 4.1$x10^4$ CFU g^{-1}. in skin). Among fish tissues; the heterotrophic bacterial population was more in the intestine than other organs of *Oreochromis niloticus.* In conclusion, the total heterotrophic bacterial population was dominated in sediment than the other samples. The present study concludes that physicochemical characters of water influence the growth and survival of total heterotrophic bacterial population in fish pond. The development of stress due to changes in physicochemical characters of water, and rich nutrient load in pond soil facilitate the growth of pathogenic bacteria which infect the culture fish *O. niloticus*. The detrivore feeding habits of *O. niloticus* is responsible for more number of bacterial populations in intestine than in other organs.

INTRODUCTION

Aquaculture is rapidly expanding worldwide, and among different fish species considered for culture, tilapia is favored most because of its suitable cultivable characteristics (Suresh and Lin, 1992).Although tilapia spp. are cultured under diversified aquaculture systems; pond

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culture of tilapia is widely practiced in several countries because earthen ponds used for fish culture producenatural fish food organisms due to soil-water interaction. To enhance fish production, fish ponds are excessively fertilized with organic and inorganic fertilizers, and fishes are fed with rich protein diets. This would lead to water quality deterioration when suitable pond management strategies arenot followed to control water quality deterioration. The increased in microbial load in unmanaged ponds reduces health and fish yield potential (Groff and Lapatra, 2000; Karunasagar and Otta, 2003). Therefore, evaluating microbial load in culture pond is fundamental and significantin aquaculture. Among microbes, bacterial pathogens assume importance as they produce great economic loss to aquaculture byproducing severe diseases, epizootics and mass mortality (Austin and Austin, 1999). Environmental changes accelerate bacterial infections (Ventura and Grizzle, 1987; Post, 1989; Zorrilla et al., 2003) and that, the rate of infection correspondingly increases with prolonged exposure of fish to stress (Sugita et al., 1985)

Extensive work has been done in certain countries in the field of finfish diseases (Ahmed et al., 2004; Islam et al., 2008; AlYahya et al., 2018). However, except for a very few studies on parasites and bacterial diseases of food fishes (Shibru and Tadesse,1979; Amare, 1986; Tefera, 1990; Eshetu, 2000), studies on bacterial diseases in fish culture in Ethiopia are scarce. As aquaculture has been identified as an important sector to ensure food security in Ethiopia, there is an imperative need to address factors that limit aquaculture production. This study focuses on heterotrophic bacterial population in water, sediment and Nile tilapia in Guder Aquaculture Farm of Ambo University. An assessment of bacterial population in fish and fish culture pond will provide an opportunity to prevent possible disease outbreaks in culture systems. This will also help to evolve suitable remedial measures to control bacterial infections in fish.

MATERIALS AND METHODS

Description of the study area

The study site, Guder Aquaculture Farm (Fig.1) is located in Guder Town at about 11 km away from the main campus of Ambo University. It is located between 1600 and 3192 meter above mean sea level. The rain fall ranges between 800 and 1000 mm and temperature between 10 ˚C and 29 ˚C. The soil characteristics are: 48% red soil, 27% black and 25% red and black soil (Anon, 2009). The soilis loamy clay, which is suitable for pond construction. Regarding weather condition, the Woreda has 27% arid, 55% semi-arid, and 18% desert. There are two distinct seasons; the dry season which occurs between October and March followed by a wet period between May and September. The main rainy season is from June to September. The area experiences moderately warm climate which is suitable for fish growth in ponds. The warmest months are from January to May with a peak in February whereas; the cold months extend from June to December. The area of the pond is 300m2 with a depth of 80 cm. The source water for the farm is from Endris River which is the tributary of Guder River.

Figure 1. Study site: Guder Aquaculture Farm of Ambo University

Enumeration of heterotrophic bacterial population from water, sediment and *O. niloticus*

Surface water samples were collected from the earthen pond by using sterilized glass bottles having 250ml capacity from about 20cm below the water surface from four locations of the pond for bacteriological investigation for a period of five months from November to March. Similarly the sediment samples were collected from the same location using submerging sterilized glass bottles and were centrifuged for decanting. For gills, intestine, kidney and skin sampling, fifty five Nile tilapia with a mean weight of 44.86g were randomly collected from the pond mentioned above. Individual fish was killed by a strong blow on the head and then surface disinfection was performed with 70% ethanol before gills, intestine, kidney and skin samples were taken aseptically. Later, 1ml of water and 1g of sediment and fish body samples were diluted (10^1-10^7 serialdilution factors) using 9ml normal saline solution. From each test tube of each sample, 100µL of sample was speared in duplicate on tryptic soy agree (TSA) plat and incubated at temperature of 37ºC for 48 hrs. The concentration of heterotrophic bacterial load at different samples was counted and expressed as colony forming unit per milliliter or gram (CFU/ml or CFU/g) (Cole et al., 1988; Austin and Austin, 1999; Pakingking et al., 2015). The plates with 30-300 colonies were used for the determination of bacterial population (Prakash and Karmagam, 2013). The bacterial colonies were observed according to shape, size, color and opacity (Garrity, 2001). All samples for the study were done in duplicate.

Pure culture of *Aeromonas* bacteria

Following morphological and colonial characteristics of bacterial on tryptone soy agar (TSA) plates, 3-5 representatives of each colony type were randomly picked from each plate and further sub-cultured to obtained pure cultures of bacterial following the method of Monghit-Camarin et al. (2020) and Pakingking et al. (2020). Later, bacterial cultures were stocked in TSA broth containing 15 % glycerol at 80 °C (Pakingking et al., 2015). Later, 1ml of sample were speared on tryptone soy agar (TSA) plat and incubated at temperature of 37ºC for 48hrs for primary isolation and enumeration of total hetrotrophic bacterial following Bergey's Manual of Systemic Bacteriology (Holt et al., 1994) using Gram-staining and biochemical tests such as oxidase, catalase and indole tests etc.

Water quality parameters

To identify the relationship between water quality parameters and bacterial population during the study period, water temperature, pH and conductivity were measured around 10 a.m. and were determined by thermometer, digital pH meter and portable conductivity cell, respectively. Transparency was measured using Secchidisc (Trivedy and Goel, 1984). Dissolved oxygen of water sample was analyzed by following Winker's or titration-based on "drop count" method by fixing the samples using Alkaline iodide and Manganese sulfate and recorded as mg/L (APHA, 1998).Salinity was measured using portable conductivity meter. Ammonia, nitrate, total nitrogen and total phosphorous were measured using calibrated visible UV spectrophotometer in the Chemistry Laboratory of Ambo University.

Data analysis

Bacterial density data was transformed into Microsoft Excel spread sheet before statistical analysis. The means of bacterial load were compared using ANOVA followed by Tukey's post hoc for multiple comparisons. Statistical Package for Social Sciences (SPSS) software version 16.0 windows were used to analyze the data with the level of significance at $p<0.05$.

RESULTS AND DISCUSSION

Water quality characteristics

The results of water quality characteristics are presented in Table 1. The results showed that DO content of the water varied between the months and it ranged between 6.3 mg/L in December and 7.25 mg/L in February. The water temperature ranged from a minimum of 18.1˚C in November and December to a maximum of 24.6˚C in February. There is an apparent difference in the water temperature between the months of the study. The lower temperature evidenced during November and December mainly coincided with the intermittent cloudy time which kept the area under cooler condition during this period. The temperature further showed a trend that it increased from January to February and a marginal decline from February to the end of March. Moreover, water pH also showed variation between the months. It was slightly acidic in November and December (6.60 - 6.65), and neutral in February and March (7.50 to 7.6). Total dissolved solid concentration was in the range of 186 - 191 mg/L. Chemical parameters like nitrate and phosphates showed marginal fluctuations between 27.1 and 33 and 1.9 and 2.11 respectively indicating the fact that it did not show much variation between the months. The salinity of pond was nil at all times. Conductivity values showed an increasing trend till February and showed a slight fall in March. February registered the highest value. Chien et al. (1999) reported that high conductivity has a direct bearing on the survival of microbes. Pond water transparency ranged from 27.3 to 34.9 cm which is within the desirable level for the culture of tilapia.

Table- 1: Physiochemical variables of pond water in different months

Water quality variables	Nov.	Dec.	Jan.	Feb.	Mar.
Water temperature (ºC)	18.1	18.1	22.2	24.6	24.2
pH	6.60	6.65	6.93	7.60	7.50
Dissolved oxygen (DO) (mg/L)	6.4	6.3	6.9	7.25	7.22
Ammonia (NH_3) (mg/l)	0.06	0.05	0.07	0.07	0.08
Nitrate (NO_3) (mg/l)	11.21	11.33	11.43	11.42	11.5
phosphate (mg/l)	1.91	1.9	1.91	2.11	2
Salinity (g/kg)	Nil	Nil	nil	nil	nil
Total dissolved solids (TDS) (ml/l)	186	186	187	191	189
Total hardness (as $Caco_3$) (ml/l)	79	79	80	79	79
Conductivity (µs/cm)	176	181	187	188	185
Secchi depth (cm)	27.3	33.1	34.9	34	34

Total heterotrophic bacterial (THB) population in water and sediment

The results of the quantitative estimation of heterotrophic bacteria in water and sediment of rearing pond in different months are given in Table 2. It is evident that the bacterial population varied between the months. Total heterotrophic bacterial (THB) population in the sediment ranged from 3.43 $x10^6$ to 5.54 x 10^6 CFU g^{-1} and in water it ranged between $1.45x10^6$ in November and $4.0x10^6$ CFU ml^{-1} in January. This finding revealed that bacterial populations were high in January and February and minimum in November in both water and sediment samples.

The results also showed that during January and February, there was maximum quantitative heterotrophic bacterial population in earthen pond when compared to November in both water and sediment samples. In the present study, it is clear that physico-chemical parameters alter the microbial environment leading to alteration in microbial community. The factors such as temperature, pH and DO when increased, the concentration of bacterial population also increased. This is because increased temperature in warmer months favors the growth of bacteria in the environment (Sugita et al., 1985; Markosova and Jezek, 1994).

Table- 2. Heterotrophic bacterial population in Water and Sediment samples

Months	Water (CFU ml^{-1})	Sediment (CFU g^{-1})
November	$1.45x10^6$	$3.43x10^6$
December	$1.88x10^6$	$4.34x10^6$
January	$4.00x10^6$	$5.00x10^6$
February	$3.89x10^6$	$5.54x10^6$
March	$3.72x10^6$	$4.64x10^6$
Mean	**$2.98x10^6$**	**$4.59x10^6$**

The mean population of bacterial in the sediment samples was 4.59 x 10^6 CFU g^{-1} and it was 2.98x10^6 CFU ml^{-1} in water, despite the fact that heterotrophic bacterial population was more in the sediment samples and enhances survival of aquatic bacteria than in water. Okpokwasili and Alapiki (1990) also observed higher bacterial population in fish pond sediment than in water. Anon (1997) also reported higher bacterial population density in the sediments than water in general due to the rich organic content of the former and lesser residence time of the microorganisms in the water column than the sediments.

Heterotrophic bacterial population in different organs of Nile tilapia (*O. niloticus*)

The distribution of heterotrophic bacteria in different organs (gills, intestine, kidney and skin) of *O. niloticus is* presented in Table 3. The bacterial population in gill filaments ranged from 1.06 ± 1.10x10^4 to 1.74 ± 10.8x10^4 CFU g^{-1}; in intestine from 1.62 ± 11.2x10^4 to 2.82 ± 13.0x10^4 CFU g^{-1}; in kidney from 0.82 ± 5.9x10^4 to 1.60±12.1.6x10^4 CFU g^{-1}; in skin from 0.48 ± 5.0 to 0.77 ± 4.1x10^4 CFU g^{-1}. Each count was the mean value of viable colonies grown on duplicate agar plates made per individual sample. There was no significant difference ($p>0.05$) during November and December of bacterial count in fish tissues, but significantly increase in February ($p<0.05$) was observed. This may be related to ambient water temperature. Similar observation was reported by Ferguson et al. (1996) who reported that change in water parameters have a positive correlation to total heterotrophic bacterial population. Pal and Das Gupta (1992) established that environment could influence the micro flora of the fish and pond system. When bacterial counts of different organs were compared, the count in the month of February was significantly increased ($p<0.05$) in intestine and gills. In this study, the presence of high bacterial population in the gills and intestine of fish might be due to the high metabolic activity of fish associated with increased feeding rates at higher water temperatures. The bacterial population observed in fish samples was highest in intestine. This may be due to the voracious feeding behavior of Tilapia which feeds on detritus, organic matter as reported by Beveridge et al. (1988). It is generally presumed that those bacteria which were consumed by fishes like tilapia are particle-bound (Bowen, 1976; Schroeder, 1978; Opuzynski, 1981). Next to intestine, higher bacterial load was found in the gills. This is mainly because of the role played by gills in filtering microscopic organisms (Hamplet al.,1983). Evidences from recent studies of feeding in tilapia suggest that small particles are entrapped among the gill apparatus in a mucous film (Drenner et al., 1987; Beveridge et al., 1988; Northcott and Beveridge, 1988).

Histological studies of the bucco-pharyngeal cavity showed that the mucous cells of the gill rakers produce a highly negatively charged mucous (Northcott and Beveridge, 1988) which may facilitate flocculation and retain very small particles. Next to intestine and gills, the bacterial count was more in kidney. Kidney being an excretory organ the bacterial population might have trapped inside the kidney in the process of excretion. Skin showed the minimum bacterial load. The reason for minimum load of bacteria in the skin may be due to its frequent contact with the contaminated water and sediment in the aquatic media.

Table- 3: Monthly mean heterotrophic bacterial population in different organs of fish

Month	Gill ($x10^4$ CFU g^{-1})	Intestine ($x10^4$ CFU g^{-1})	Kidney ($x10^4$ CFU g^{-1})	Skin $x10^4$ CFU g^{-1}
November	1.06±1.10	1.62±1.12	1.06±1.5	0.76±0.26
December	1.13±1.06	2.03±3.40	1.07±1.3	0.68±0.49
January	1.14±2.10	1.67±1.98	0.82±5.9	0.48±0.50
February	1.49±1.28	2.82±1.30	1.60±1.21	0.77±0.41
March	1.74±1.08	2.36±1.45	1.27±2.26	0.75±0.40

Heterotrophic Bacterial population in fish, water and sediment

Based on morphological and biochemical characteristics, bacterial isolates namely *Escherichia coli, Aeromonas, Pseudomonas, Salmonella, Staphylococcus, and Streptococcus* from fish, water and sediment samples were identified.

***Aeromonas* in water and sediments**

The *Aeromonas* bacterial count in water and sediment is presented in Table 4. It ranged from 1.01 x 10^6 to 1.42 x 10^6 CFU $ml^{-1}$and 1.23 x 10^6 to 1.70 $x10^6$ $CFUg^{-1}$ in water and sediment samples, respectively. The bacterial population was more in the sediment ($1.47x10^6$ g^{-1}) than in water samples ($1.25x10^6$ ml^{-1}). This observation is related to the fact that sediment contains more valuable nutrients for the growth of microorganism than the water column. This has to be ascribed to the sedimentation of the bulk of nutrients added in the form of fish feed or organic wastes for pond fertilization. Similar trend was noticed by Okpokwasili and Alapiki (1990) who related this with the decomposition of these organic adjuncts used for pond water fertilization. Furthermore, the favorable temperature and the permissible dissolved oxygen level of the sediment would have enhanced the survival of the bacteria (Ogbondeminu, 1993). The bacterial population in the month of January in both water ($1.42x10^6$ CFU ml^{-1}) and sediment (1.7x106 $CFUg^{-1}$) followed by February which registered the values as $1.39x10^6$ CFU ml^{-1} for water and $1.54x10^6$ CFU g^{-1} for sediments. The bacteria count in the months of November for both water ($1.01x10^6$ CFU ml^{-1}) and sediment ($1.23x10^6$ CFU g^{-1}) were less when compared to January and February. In general, the occurrences of bacterial population in fish in rearing ponds exhibited variation in relation to different months. It was reported that alteration in environmental parameters influences growth and survival of micro flora in aquatic environment.

Table – 4: *Aeromonas* bacterial population in water and sediment in different months

Months	Water(CFU $ml^{-1}10^6$)	Sediment (CFU $g^{-1}10^6$)
November	$1.01x10^6$	$1.23x10^6$
December	$1.08x10^6$	$1.44x10^6$
January	$1.42x10^6$	$1.70x10^6$
February	$1.39x10^6$	$1.54x10^6$
March	$1.33x10^6$	$1.42x10^6$
Mean	**$1.25x10^6$**	**$1.47x10^6$**

Relationship between water parameter and *Aeromonas* bacteria

The relationship between water quality parameters and *Aeromonas* bacteria in water and sediment in relation to water temperature is presented in Table 5. The relationship between physico-chemical parameters and bacterial count attracted much attention (Ogbondeminu and Adeniji, 1984; Ferguson et al., 1996). The results showed that bacterial counts were directly related to the various water variables examined. From November to December when DO, water temperature, pH and ammonia were found to be lower, the bacterial population was also lower, and again the bacterial population was higher in January and February.

Table -5: *Aeromonas* bacteria in relation with water parameters

Month	DO (mg L^{-1})	Temperature (^{0}c)	pH	NH_3 (mg L^{-1})	Mean *Aeromonas* population (CFU ml^{-1})	
					Water	**Sediment**
Nov.- Dec.	6.35	18.1	6.62	0.06	$1.05x10^6$	$1.34x10^6$
Jan. - Feb.	7.07	23.4	7.26	0.07	$1.41x10^6$	$1.62x10^6$

Morphological and biochemical characterization of *Aeromonas* bacteria

The characteristics recorded are Gram's negative, rod shape with round end and motile (Buller, 2004). Biochemical properties of *Aeromonas* bacterial isolates are described in Table 5. The isolates were positively reacted with cytochrome oxidase, catalase, gas production, and lactose, glucose, and sucrose fermentation and motile whereas the isolates were negative starch hydrolysis. H_2S production was positive on motility medium and negative on Triple sugar Iron Agar (TSIA). Microbiology Laboratory Guidebook (Bonnie et al., 1998) describes the biochemical characteristic of *Aeromonas* bacteria. Catalase and oxidase positive and, hydrogen sulfide production on Triple sugar Iron Agar (TSIA) negative, and growth temperature tests were conducted to demonstrate the biochemical characteristic of *Aeromonas* bacteria.

Table- 6. Cell morphology and biochemical characteristics of *Aeromonas* spp.

Test	Results
Shape	Straight, rod, pairs with round end
Motility test	Motile
Gram staining	-ve
Colony color	Yellowish with opaque
Hydrogen sulfide test	+ve/ -ve
Oxidase test	+ve
Catalase test	+ve
Starch hydrolysis test	-ve
Gas production	+ve
Lactose/sucrose/glucose fermented	+ve
Acid production	+ve
Triple sugar Iron Agar	Acid butt with gas

Note: Result from test conducted +ve indicate positive result

CONCLUSION

The present study revealed that physicochemical characteristics of water influence the growth and survival of heterotrophic bacterial population in fish culture pond. Increased water temperature, favorable dissolved oxygen content and pH facilitate the proliferation of heterotrophic bacterial population in water. Excess feed remains, rich nutrient content, organic matter and their longer resident time in pond soil profoundly favor the increase in bacterial count in sediment than water. The development of stress due to changes in physicochemical characteristics of water, and rich nutrient load in pond soil facilitate the growth of pathogenic bacteria which infect the culture fish *O. niloticus*. The detrivore feeding habits of *O. niloticus* is responsible for more number of bacterial populations in intestine than in other organs.

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