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An overview of the current status of Lake Jipe and its biodiversity dilemma

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Abstract

Lake Jipe, is a shared water resource between Kenya and Tanzania located at the East African Coast is under multiple pressures. The present study assessed the current state of Lake Jipe and its biodiversity dilemma. Random sampling was conducted at 14 sampling points set at equidistant parallel to each other. Sampling depths and location coordinates were measured using Solar Transducer and GPSMAPS® 65 s. In situ water quality parameters were measured using YSI Pro Plus multiparameter; water samples for nutrients analysis were collected and preserved in cooler boxes prior transportation to Kenya Marine and Fisheries Research Institute (KMFRI) laboratory for analysis according to ALPHA 2005. Socio-economic data in relation to status of Lake Jipe ecology were generated using Key Informants Interviews at identified beaches along Kenya and Tanzania. Present findings indicated that the lake has receded from the original 108.72 Km^2 to 27.32 Km^2 with annual temperatures, dissolved oxygen and conductivity of 28.58 ± 0.95, 5.19 ± 00 and 799.24 ± 69.41, respectively, for dry season. Wet season recorded 31.21 ± 0.31, 4.16 ± 0.01 and 882.44 ± 57.41 for temperature, dissolved oxygen and conductivity, respectively. Agricultural activities have significantly (90%) contributed to the lake levels decline and further affected the lakes' aquatic biodiversity. Among the most affected are the commercially important endemic fish species of the lake of which *Oreochromis jipe* has experienced the greatest decline. Overfishing, use of illegal unreported and unregulated fishing gears, intensified fishing along protected fish breeding areas as well as poor management and uncoordinated conservation efforts have significantly contributed to the decline of fish catches from 348 kg of *O. jipe* in 2016 to 90 kg daily catches in 2022. Consequently, the lake is in the verge of extinction if no action is taken. This calls for awareness on the significance of the L. Jipe ecosystems and its immediate and long-term benefits. Further, there is need to revive and promote alternative economic activities including sustainable aquaculture and agriculture to local communities.

KEYWORDS
biodiversity, fishery, endemic species, agriculture, conservation

1 | INTRODUCTION

Lake Jipe is located in East Africa, along the south-eastern border of Kenya and Tanzania within 03°27′00″ S and 37°43′48″ E (Mwachiro et al., 2012). It is a shallow lake with original area cover of ≈100 km^2 with recent studies estimating the area at 30 km^2 as a result of receding water levels (Ndetei, 2011). Its main inlet is Lumi River descending from Mount Kilimanjaro which and later empties into Ruvu River and Nyumba Ya Mungu Dam (Republic of Kenya, 2022). The lake has a long history of supporting artisanal fisheries by the local communities across the two neighbouring countries (Froese & Pauly, 2019; Ministry of Fisheries and Livestock Development, 2001). Jipe tilapia (*Oreochromis jipe*), African catfish (*Clarias gariepinus*), Barbus spp. and *Labeo* spp. are the known indigenous species of Lake Jipe with a past socio-economic importance. Other species documented in the lake are *Astatotilapia bloyeti*, *Clarias massambicus*, *Barbus paludinosus* and *Petersius tangensis* (Dadzie et al., 1988). However, a decline in the lake fisheries led to the introduction of Tilapia singida (*Oreochromis esculentus*) which later led to the displacement of *O. jipe* in the lake (Twong'o et al., 2002). This then prompted the introduction of *O. niloticus* in 2015 by the County Government of Taita Taveta in collaboration with the National Government Fisheries Department to boost the lake fishery (Ogutu-Ohwayo, 1990). Unfortunately, *O. niloticus* has over time proved to be more aggressive hence leading to a further decline of *O. jipe* an endemic species to Lake Jipe (Njiru et al., 2006). This could be coupled with reported cases of *O. niloticus* and *O. jipe* hybridization (Bradbeer et al., 2018; Deines et al., 2014; Omweno et al., 2020), rising water temperatures against declining lake depth, increased turbidity and reduced breeding grounds. The lake is a major watershed which contributes significantly to biodiversity, food security and nutrition, economic empowerment and recreation (Ndetei, 2011). The lake's watershed has over the years supported the growing human population whose activities have significantly affected the aquatic ecosystems biodiversity. Equally, the wildlife and livestock pressure from the Kenyan unprotected side on access to water and foliage around the lake shore has contributed significantly to vegetation loss and siltation (Odada et al., 2006). Over the years, the lake has undergone several ecological changes associated with physical, chemical and biological processes including the rapid growth and expansion of *Typha domingensis* and introduction of exotic fish species has led to the decline in fish catches and changes in the status of the lake's biodiversity. Despite numerous benefits from the lake, the lack of an integrated ecosystem management plan supported by the two neighbouring countries has created a serious gap on the resource management and conservation (Odada et al., 2006). Therefore, this paper discuss the current state of the lake and possible paradigm shift in management strategies of Lake Jipe ecosystem for sustainable use.

2 | MATERIALS AND METHODS

This study was carried out at Lake Jipe along Taveta Sub-County, Taita Taveta County, Kenya and in Mwanga District, United Republic of Tanzania (Figure 1). The lake's major water sources are Mt. Kilimanjaro's Lumi River supported by several temporary streams from the Pare Mountains in Tanzania. The lake was divided into 14 sampling points set at equidistant parallel to each other from the south to the North. The wet and dry seasons sampling points covered Northern, Central and Southern parts of the lake. Based on the lakes' shape and to ensure total sampling coverage, it was divided longitudinally into two equal halves with the help of a handheld GPS machine and further horizontally split into 14 quadrants each measuring ≈1.95 km^2. In addition, the sampling points depths were measured using Solar Transducer and GPS coordinates recorded using GPSMAP® 65 s. Multi-Band GPS Handheld with Sensors was used to inform lake surface area. In situ physical chemical parameters for dissolved oxygen (DO), temperature, pH, conductivity, salinity, oxidation reduction potential (ORP) and turbidity levels were taken using water quality

FIGURE 1 Map showing Lake Jape (Orina, 2022).

YSI Pro Plus multiparameter (17 L102252) and similarly water samples collected for nutrient analysis using 250 mL amber light bottles. The bottles were rinsed using distilled water prior to use and subsequently rinsed three times using sample water. The samples were preserved using four drops of aqueous sodium thiosulphate solution then wrapped with foil before transporting the samples in cooler boxes with ice cubes to KMFRI laboratory for TN, TP and TAN analysis according to APHA (2005).

The present study further applied a cross-sectional survey design to collect data using a pretested structured questionnaire administered to randomly selected fisherfolk. Further, Key Informant Interviews (KIIs) were undertaken targeting the Beach Management Units leaders and the Fisheries Officers. Random sampling was used to select 30 fisherfolk for questionnaire survey. Fisherfolk were from the three selected beaches along Kenya and Tanzania namely Kachero, Mkwanjuni and Kilometa. The survey questionnaires focused on; socio-economic activities, water abstraction, fish catch composition and species biodiversity in Lake Jipe.

2.1 | Data analysis

All data collected were checked for any inconsistencies; outliers and anomalies were communicated to the respective teams. Data for water quality and socio-economic were cleaned, coded and keyed into MS excel following statistical analysis using SPSS software Version 2020.

3 | RESULTS

3.1 | Surface area of Lake Jipe

The current study findings indicate that Lake Jipe covers a water surface area of 27.32 km^2, stretching 12 km North–South and an average width of 2.28 km. This is a shallow lake with an average depth of 0.98 ± 0.07 m with the deepest parts being 1.5 m, all located to the North of the lake on either side of the two countries (Figure 1).

3.2 | Water quality parameters

Present findings reported wet season means of 28.54 ± 0.95°C, 5.19 ± 0.00, 0.44 ± 0.004, 799.24 ± 69.41 and 151.36 ± 6.09 for temperature, DO, salinity, conductivity and ORP, respectively. Dry season recorded an average of 31.21 ± 0.31°C, 4.16 ± 0.01, 0.49 ± 0.004, 882.44 ± 57.41 and 182.52 ± 5.67 for temperature, DO, salinity, conductivity and ORP, respectively. However, there was no significant changes recorded on both seasons (Table 1). Nutrient loads were recorded to be high and low at Central Eastern and Northern Transects, respectively. CET recorded 585.45 ± 83, 267.23 ± 5 and 4.32 ± 3 for TN, TP and ammonium, respectively, in the dry season while the wet season recorded 691.31 ± 33, 374.81 ± 3 and 2.86 ± 3 (Table 2).

TABLE 1 Annual mean water quality parameters of Lake Jipe.

Parameters	Wet season mean	Dry season
Depth	0.98 ± 0.07	0.89 ± 0.05
Temp	28.54 ± 0.95	31.21 ± 0.31
DO	5.19 ± 0.00	4.16 ± 0.01
pH	6.43 ± 0.04	6.63 ± 0.03
Sal	0.44 ± 0.004	0.49 ± 0.004
TDS	594.74 ± 8.28	356.61 ± 3.73
Cond	799.24 ± 69.41	882.44 ± 57.41
ORP	151.36 ± 6.09	182.52 ± 5.67

Note: Temperature (Temp) = °C, Dissolved Oxygen (DO) = mg/l, Salinity (Sal) = g/l, Conductivity (conduct) = ppt, Total Dissolve Solids (TDS) = Oxidation Reduction Potential (ORP) = mV.

3.3 | Socio-economics

A total of 30 respondents were interviewed with male (70%) being the most dominant gender due to the present study focus on fisherfolk who are mostly men. Men engaged in activities like operating boats, setting fish nets at the lake, fishing and maintenance of fishing vessels whereas women participated in gutting, cleaning, drying, smoking, frying and packing fish for the market. The ages of the respondents also varied with the highest number reported being >30 ≤50 years (50%) followed by ≤30 years (40%) and finally >50 years (10%). This indicated that fishing activities are mainly dominated by a youthful fisherfolk.

The main agricultural livelihood among riparian communities is fishing except those occupying the densely populated northern parts of Mbogoni ward within Taveta Sub-County. Mata ward of Taveta Sub-County is mainly pastoralists due to human-wildlife conflict. The survey recognized that within Mata ward fishing is the only source of livelihood as wildlife from the nearby Tsavo West Game Park destroyed crops hence making farming activities difficult to practice. Further, trading was also practiced around the beaches where traders bought fish at the landing sites. However, they experienced low fish prices due to small size catches, distance from the market and poor beach management structures.

The present study further recognized the lack of clean water for domestic use due to lack of piped water infrastructure both in Taveta Sub-County in Kenya and Mwanga District in Tanzania. Majority of the respondents' sourced water from the lake (70%) followed by Lumi River (20%), a minority 10% have boreholes. The survey also aimed at understanding the indigenous knowledge of the shrinking lake ecosystem, 100% of the respondents reported that the total area of Lake Jipe is decreasing. The respondents attributed the lake water level decrease to two major reasons; irrigation and other agricultural related activities from the upper catchment was the most significant (90%) cause of lake level decrease, while climate change

TABLE 2 Lake Jipe annual nutrients load along four major transects.

Season	Station	TN (μgL^{-1})	TP (μgL^{-1})	Nitrates (μgL^{-1})	Nitrites (μgL^{-1})	Ammonium (μgL^{-1})	Alkalinity (mgL^{-1})	Hardness (mgL^{-1})
Dry	NT	217.25 ± 67	155.31 ± 5	5.98 ± 2	2.27 ± 1	2.22 ± 1	45.27 ± 12	38.43 ± 5
	CET	585.45 ± 83	267.23 ± 5	10.81 ± 7	4.13 ± 3	4.32 ± 3	53.33 ± 2	47.62 ± 5
	CWT	448.66 ± 65	245.72 ± 3	7.61 ± 4	3.65 ± 1	3.14 ± 2	51.65 ± 5	40.41 ± 5
	ST	376.27 ± 25	186.92 ± 2	7.43 ± 2	2.99 ± 1	3.18 ± 1	49.61 ± 5	42.29 ± 5
Wet	NT	384.42 ± 83	231.57 ± 3	7.74 ± 3	2.85 ± 2	2.01 ± 2	38.05 ± 6	26.17 ± 4
	CET	691.31 ± 33	374.81 ± 3	12.01 ± 2	4.67 ± 3	2.86 ± 3	31.33 ± 8	27.02 ± 5
	CWT	448.66 ± 29	363.45 ± 5	8.92 ± 2	4.21 ± 2	2.23 ± 2	27.34 ± 4	29.62 ± 2
	ST	576.27 ± 47	277.63 ± 4	8.05 ± 3	3.41 ± 2	2.38 ± 1	30.29 ± 3	26.19 ± 3

Abbreviations: CET, Central Eastern Transect; CWT, Central Western Transect; NT, Northern Transect; ST, Southern Transect; TN, Total Nutrients; TP, Total Phosphorus.

accounted for a paltry 5%. The respondents decried lack of access to the lake due to dense *Typha domingensis* macrophytes invasion on most parts of the lake shores. The respondents on the Kenya side of the lake associated growing siltation levels to growing domestic and wildlife animals trooping daily to the lake in search of water. Human-wildlife conflict has increased with occasional reported injuries and deaths due to growing forage opportunities by elephants along the vegetated shores which could also be serving as lake access points or fishing grounds.

3.4 | Fish catch landings

Among the challenges facing the lake fishery were climate change, overfishing, use of illegal unreported and unregulated fishing gears, unprotected fish breeding areas as well as poor management and uncoordinated conservation efforts (Omweno et al., 2023). The county fisheries authorities and beach management units' leadership confirmed that an estimated 80% of the fishermen fish daily while 10% fish either weekly or biweekly resulting in unprecedented pressure of the lake fishery. This indicates that there is high probability of fish extinction due to overfishing. The species composition of the catch had *O. niloticus* accounting for 50%, *O. jipe* (10%) while both *O. niloticus* and *O. jipe* accounted for 40% (Figure 2). While *O. niloticus* was reported to increase in catches, *O. jipe* had declined significantly over the years with total daily landings in 2022 being 90 kg compared to 348 kg in 2016 (Fisheries Annual Statistical Bulletin, 2016).

From the present survey, 40% respondents recorded an increase in catch landings since 2017 following the introduction of *O. niloticus* in 2015 by the National government, State Department of Fisheries in collaboration with the Taita Taveta County Government Fisheries Department. The introductions came as a result of the dwindling catches of *O. jipe*, *C. gariepinus* and *O. esculentus* (Figure 3). This is has resulted in the species richness shift from the traditional species *O. jipe*, *C. gariepinus* and *O. esculentus* to *O. niloticus* since their introduction in 2016 (Omweno et al., 2023). Further, there are reported cases of possible hybridization between the lakes tilapiines (Bradbeer et al., 2018).

4 | DISCUSSION

The lake has receded over time as recorded by Johnston, 1886 who in his expedition recorded 108.78 Km^2, latter Lowe (1951) recorded 38 km^2 and most recently (2022), the Global Nature Funds Research Report documented 28 km^2 and now the current study documents 27.32 km^2. The current study confirms a receding trend for Lake Jipe which is manifestation of previously documented multistressors (IUCN, 2021; Ndetei, 2011; Ngugi et al., 2015; Odada et al., 2009; Omweno et al., 2023; Rosemond et al., 2015; Zedler & Kercher, 2005).

4.1 | Ecological changes

The water quality of the lake has deteriorated immensely over the past few decades due to eutrophication as a result of increased nutrient load from the catchment area (Ndetei, 2011). Kenya side has the greatest impact with loose soil and loss of vegetation being evident along the plains compared to the Tanzania Pare Mountains (Figure 1). The intensified human water need for agriculture, livestock and domestic use has significantly reduced the flow of water from Mt. Kilimanjaro through Lumi River into Lake Jipe. These has contributed to receding water cover area by 2.68 km^2 in the last two decades. As a result of continuous water receding levels, vegetated fringes previously serving as fish breeding grounds have experienced ecological shifts thus no longer conferring breeding fish same benefits (Mwachiro et al., 2012). The land degradation and wetlands deterioration is grave on the Kenyan plains as a result of missing economic signal to locals and policy makers concerning ecosystem values. Among the significant impacts witnessed along Lake Jipe shores included; siltation, increased macrophytes area cover, use of illegal, unregulated and unprotected fishing gears, over fishing, unregulated

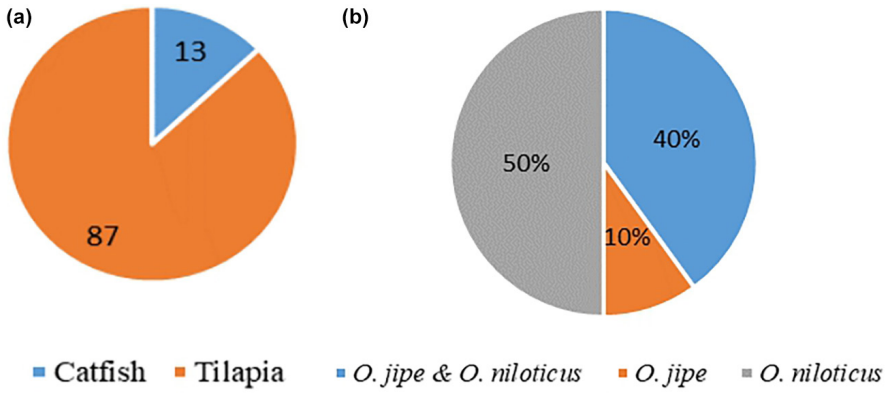

FIGURE 2 Fish species composition of the catch landings 2016 (a) and 2022 (b).

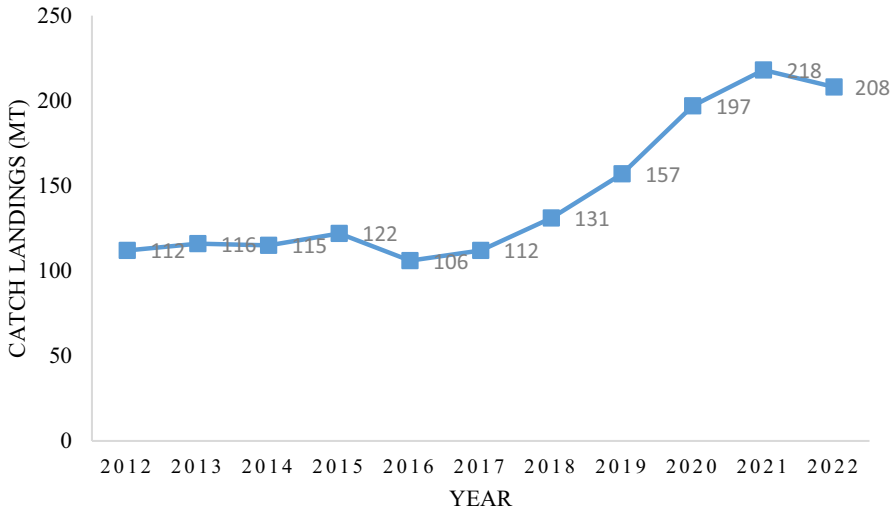

FIGURE 3 Fish catch landing trends at L. Jipe over the years.

pastoralism, erosion and dry river beds, loss of vegetation cover and intensified human-wildlife conflicts.

4.2 | Habitat degradation and biodiversity changes

Lake Jipe ecosystem just like any other ecosystem is rich in biodiversity and act as the main watering point for wildlife in Tsavo West National Park (Kenya Wildlife Service, 1998). The lake acts as home for hippos, crocodiles and other wildlife species especially water birds, elephants, zebras, impalas and gazelles. The extensive cover of macrophytes especially Typa extending up to Lumi and Ruvu Rivers act as habitat for several bird species and breeding grounds for fish especially *O. jipe* thus supporting the local fishing industry (Shechonge et al., 2019). However, the effects of fishing pressure from locals and irrigation activities in the upstream has resulted to the receding water levels and decline of fish stocks coupled with increased *Typha domingensis* area coverage (Ministry of Livestock and Fisheries Department, 2001). This causes massive loss of nursery grounds for *Oreochromis Spp* and feeding niche for higher animals. As a result of sustained eutrophication, overfishing and exotic fish species competition against *O. jipe*, the habitat integrity has been greatly compromised resulting in reduced lake depth, poor water quality and competition over limited primary and secondary productivity. Overall effect is a diminishing biodiversity due to fragmented food webs and food chains. The present study identified the following activities and their environmental impact along the L. Jipe aquatic ecosystem as summarized below (Table 3).

4.3 | Management strategies

Lake Jipe borders two countries; Kenya and Tanzania thus environmental impacts from its catchment has adverse effects on entire lake. Most of the pollution reaching the lake is from its basin, thus the lake needs to be treated as a single ecosystem, requiring both national and regional cooperation. Trans-boundary multistakeholder engagement is key to saving the lake and its biodiversity with a focus on nature based solutions. There is equally the need to revive alternative economic activities including aquaculture and sustainable agriculture to offer alternative livelihood.

5 | CONCLUSION

Lake Jipe is at the verge of extinction if no action is taken. Globally, 50% of wetlands have been lost as a result of human degradation

TABLE 3 Summary of socio-economic activities and environmental impacts on Lake Jipe Kenya.

Activity	Environmental impact
Agriculture	Accelerate soil erosion and siltation causing negative impacts on water quality
Irrigation	Changes in water discharge, flow rate, water levels, depth and eutrophication
Settlements around the shore	Overfishing, soil erosion/siltation and pollution causing negative impacts on water quality
Livestock and wildlife movement	Overgrazing causing siltation in the lake, reduced forage
Dredging and channelization	Changes in water discharge, flow rate, water levels, depth, water pollution, landscape alteration and changes in river direction
Fishing	Overexploitation of fishery resources
Deforestation	Accelerate siltation, loosening of terrestrial soil
Mining	Exposure to heavy metals pollution

and climate change (Davidson, 2014). Prolonged drought and unpredictable rain patterns are clear signs of climate change. The receding of the lake level and colonization of the silted lake shores has a far reaching effect on the fisheries and the general aquatic biodiversity. This is necessitated by the anthropogenic activities mainly unregulated livestock population and land-based agricultural activities including use of water for irrigation. The Lake Jipe community seem to seek immediate social and economic interventions to their livelihoods against sustainable resource exploitation. This in addition to already existing pressures from anthropogenic activities, wildlife and invasive species, the fishery of Lake Jipe and mainly *O. jipe* is at the verge of collapse.

Therefore, this calls for awareness on the significance of the L. Jipe ecosystems and its immediate and long-term benefits. The County Government of Taita Taveta in Kenya and the Mwanga District leadership in Tanzania with the support of their respective national governments stand a better chance of developing a transboundary conservation strategy. The conservation strategy will require the engagement of all relevant stakeholders including the local communities, relevant government agencies and the private sector. This will go a long way in recovering the lost vegetation cover, minimize soil erosion and siltation, reduce human-wildlife conflict and illegal, unreported and unregulated fishing. The vulnerable riparian communities require alternative sources of livelihood as a sustainable way of easing the fishing pressure and over reliance on livestock which is equally vulnerable to climate change.

To conserve the endangered commercially important *O. jipe* and other fish species indigenous to Lake Jipe, aquaculture is an immediate alternative to fish protein demand locally and beyond. Aquaculture also has the potential for in situ conservation through identification of breeding grounds, recommending the areas for gazettement followed by multiplication and restocking of *O. jipe*. In the long-term, dredging of rivers feeding the lake and the main lake will significantly contribute to the lake biodiversity recovery.

The youthful fisherfolk community engaging in illegal, unregulated and unreported fishing activities are highly guided in their activities by the lack of the lakes historical background, value and fragility. The same applies to those engaged in land based agricultural activities whose irrigation intensity and herd sizes are increasing daily. Community environmental awareness could not yield immediate benefits but will overtime result in a sustainable livelihood as has been the case in other parts of the world and thus the lake still has an opportunity for recovery if all parties unite in its restoration.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data for this manuscript will be availed whenever it might be required as shall be request.

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