Impacts of introduced species on the fishery potential, ecology and native tilapia populations of Lakes Victoria and Jipe, Kenya

Job Ombiro Omweno (omwenojob@gmail.com)
Kisii County Government
Reuben Omondi
Kisii University
Frederick M. Ondemo
Kisii University

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Abstract

Species introductions have impacted the fishery potential, ecology and native fisheries populations of Lakes Victoria and Jipe. *Oreochromis esculentus* and *Oreochromis niloticus* have been widely introduced outside their native range establishing feral populations. However, the impacts of invasive species on management of native species biodiversity has not been documented. The establishment of exotic *O. niloticus* species populations in Lake Victoria has been accompanied by declining native populations of the *O. esculentus* and *Oreochromis variabilis*. These declines have been accelerated by the introduction of Nile perch, *Lates niloticus*, which preys upon the native *O. esculentus*, and overfishing of native fisheries which have slow growth rates and low fecundities. Moreover, nutrient pollution and eutrophication have impacted negatively the the food resources for native Singida tilapia *O. esculentus*. Native Jipe tilapia, *Oreochromis jipe* is limited in distribution to a small native range in the Pangani system comprising of Lake Jipe, the Pangani River tributaries and the downstream Nyumba ya Mungu Reseivoir. In Lake Jipe, two non-native species *O. niloticus* and *O. esculentus* have been introduced. Although the impact of *O. niloticus* on native *O. jipe* populations has not been documented, *O. jipe* has witnessed dwindling catches since the introduction of *O. esculentus* from the downstream reservoir. The decline can also be attributed to overfishing and the changing ecology of the lake after proliferation of emergent macrophytes such as *Typha domingensis*. There is need to formulate management policies to monitor and control fishing effort, pollution and protecting the lake and its catchment from degradation caused by human activities.

1. Introduction

The growth and development of aquaculture and stock enhancements have been associated with widespread introduction of fish species into outside their native range [1, 2], resulting to unprecedented impacts on native species and inland ecosystems [3]. For instance, the Tilapias endemic to the African continent have been introduced deliberately or unintentionally to more than 114 countries globally, where they have established feral populations [4]. Whereas deliberate introductions to novel ecosystems are to some extent justifiable, unintentional introductions have also occurred through escape from aquaculture facilities [5], [6]. Translocation of exotic tilapiines into non-native ecosystems has caused ecosystem degradation due to competition with and displacement of native species [5], and loss of native genetic materials through interspecific hybridization [7]. However, species introductions has become almost inevitable because of great contributions made by introduced fisheries to fish landings, and the residual incomes generated by fisher folks [4]. Kenya is endowed with high diversity of native tilapia fisheries such as *Oreochromis variabilis*, *Oreochromis esculentus*, *Oreochromis baringoensis* and *O. jipe* form a significant proportion of inland fisheries in lakes Victoria, Baringo and Jipe [8]. Most of these species occupy small native ranges [9], [10]. However, a successful introduction of exotic tilapia such as *O. niloticus* that helps to boost the fisheries productivity of inland lakes since the 1960s has accelerated the loss of native tilapiines [11]. The world wide introduction of *O. niloticus* has been considered as the most suitable option of promoting the future increases in fish production [12]. The species displays a high aquaculture potential due to its ability to attain consumer demand driven sizes [5], [7], [13]. Managing the invasive species poses a challenge to aquaculture expansions due to paucity of information on the current species distributions of both the native and exotic species outside their native ranges [14]. Nevertheless, aquaculture trials have been conducted on the large-sized aquaculture such as *Oreochromis niloticus*, *Oreochromis esculentus* and *Oreochromis jipe* [15], with the possibility of introducing these species within their native range.

1.1 Ecosystem degradation by human activities

An interplay of several factors have contributed to catchment degradation that has disrupted synchronized growth, breeding and reproductive cycles of most aquatic species [16]. Increased runoff discharge and sedimentation presents dire ramifications on aquatic ecosystem health and biodiversity [17]. This can be traced to rapid population growth in riparian areas accompanied by unplanned infrastructural developments which presents many perennial challenges to the ecosystem integrity and sustainability of most inland lakes [18]. For instance, the replacement of indigenous phreatophytes by exotic *Eucalyptus spp* trees which suppress the growth of creeping plants leaves the land bare and vulnerable to erosion [19], [20]. This has resulted in large volumes of urban, municipal and agricultural wastes from point and diffuse sources being discharged into lake ecosystems by runoff [21]. Eutrophication in Lake Victoria has reportedly altered the Nitrogen-Phosphorus ratio resulting to change in the phytoplankton community from diatoms to blue-green algae and consequently changing the fish community from the dominance of native tilapiines to nonnative fisheries dominated by *O. niloticus* which is capable of utilizing the blue green algae. Turbidity and euthrophication have resulted to declining phytoplankton diversity and succession by species of cyanobacteria, such as *Microcystis spp.* which possess the vacuoles for buoyancy and are capable of nitrogen fixation [22]. This could be due to increased environmental perturbations such as encroachment and conversion of lacustrine wetlands into human settlements and farmlands, resulting to increased nutrient loading and siltation. Degradation of wetlands has been identified as a potential cause for the decline of both native and exotic species of the genera *Oreochromis* and *Coptoton* that utilize wetlands as breeding and feeding areas [23]. Loss of native biodiversity limits the possibility of future increases in wild fisheries and diversified aquaculture production [24]. Approximately 50% of wetlands have been lost globally due to degradation by human activities [25]. In Kenya, the fringe wetlands in the inshore areas of lakes Victoria, Naivasha and Jipe have been serious degradated by human activities such as wetland conversion for agriculture and urbanization. This has resulted to lake level fluctuations and ecological disruptions during heavy rains [26]. Increased anthropogenic activities result to destabilized ecosystems characterized by loss of salient functions and the displacement of the keystone species [27].

2. Review Methodology

The current review is a result of in-depth analysis and organization of information from various related peer-reviewed publications and research reports that met the set criteria for inclusion in this study. The study adopted a comprehensive and detailed literature review using both scoping and systematic methodological approaches that focused on the invasiveness of *O. niloticus* and *O. esculentus* in inland lakes [28], [29]. This review discusses the changing fishery trends of the fisheries after the introduction of non-native species, *O. niloticus* in lakes Victoria and Jipe and *O.esculentus* in Lake Jipe. To achieve the set objectives, a wide range of keywords (closely related to Nile tilapia and introduced species) were searched in online database tools. The search was narrowed and refined using Boolean operators ('OR', 'AND' and 'NOT') were appropriately used in the various scientific databases and search engines, such as Google Scholar, Research Gate, Science Direct, and Web of Science. Published articles and technical reports linked to the key words were analyzed to select the most relevant and appropriate information to achieve the set objectives that were included in this literature review. The information was organized into copies of excerpts according to topics and research gaps identified for further research.

2.1 Description of lakes Victoria and Jipe

Lakes Victoria and Jipe are shared ecosystems (Fig. 1). The lakes Jipe and Victoria comprise of a multi species fishery comprising of the dominant tilapiines *O. niloticus* and *O. jipe* respectively, and *O. esculentus* as common species in both lakes. Lake Victoria is the second largest freshwater lake in the world. The lake extends the trans-boundary region of Kenya, Uganda and Tanzania between latitudes 0°20'N-03°S and longitudes 31°39'E-34°53'W [30]. Lake Jipe (03°35'S and 37° 045'E), is a rare biodiversity hotspot located in a semi-arid region in the leeward south eastern slopes of Mt. Kilimanjaro in the Pangani River catchment of Kenya and Tanzania [31].

The Pangani River system is the second-most important river ecosystem in Tanzania that provides water for HEP power generation and irrigation and domestic use. Increased unsustainable land use activities have reduced the size of Lake Jipe from the originally 100 km^2, to approximately 39 km^2 [32]. Lake Jipe supports cross-border socio-economic and ecological activities such as subsistence fisheries and water supply for irrigated agriculture. The lake is fed by River Lumi, and outflows into River Ruvu located in the Pangani system [32]. The reduction in lake bathmetry and surface area may also be due to diversion of the major inflow, the Lumi River into River Ruvu instead of flowing into the Lake Jipe. This has resulted to extensive inshore coverage by the emergent macrophytes such as *Typha domingensis* resulting to decreased lake levels and surface area.

This study reviews the recent declining trends in *O. esculentus* and *O. jipe* fish populations within their native ranges following the introduction and subsequent invasion by *O. niloticus*.

3. Review Findings

3.1 Tilapia fisheries

Tilapia cichlid fishes are grouped into three genera; *Oreochromis*, *Sarotherodon* and *Coptodon* [33]. More than 90 species of Tilapia can be distinguished by high level of parental care which involves building and guarding their spawning nests to ensure high survival rates for the juveniles [34], [35]. Whereas genus *Coptodon* displays primitive substrate spawning strategy, *Sarotherodon* and *Oreochromis* exhibit advanced mouth brooding strategy [36]. Genus *Oreochromis* comprises of more than 42 species which are mostly distinguished by the banding pattern in their caudal fin. The genus is among the most heavily exploited taxa, which have been transfered and introduced to many parts of the world primarily for aquaculture and argumentation of capture fisheries [37], [38]. Nevertheless, despite displaying successful spawning strategies, some critically endangered native species of the genus *Oreochromis* are characterized by slow growth rates and low fecundities which contribute to their dwindling trends (Table 1). For instance, *O. niloticus* has reported a fecundity of over 8,000 eggs distributed over short spawning intervals [39], while small sized *O. jipe* exhibits an average fecundity of ~ less than 1000 eggs [40].

Table 1
Native *Oreochromis* species in the Pangani Catchment considered in this study

Species	Common name	IUCN status	Native range	Introduction status
O. esculentus	Singida tilapia	Critically endangered	Lake Victoria basin	Introduced in Pangani Catchment
O. niloticus	Nile tilapia	Not assessed	Nile, W. Africa, L. Tanganyika, Yarkon River	Introduced in L. Victoria and the Pangani Catchment
O. jipe	Jipe tilapia	Critically endangered	Pangani Catchment	Culture trials in Kenya and Tanzania

Nile tilapia, *Oreochromis niloticus* is one of the most commercially important tilapiines that has been introduced all over the world for aquaculture expansion and stock enhancement [38]. The species makes significant contributions to lucrative commercial aquaculture fisheries globally [41]. In Kenya, it has been introduced into lakes Naivasha, Victoria, Jipe and several dams to provide commercially exploitable fisheries. Unlike native tilapia, *O. niloticus* can adapt well to both fast flowing and slow flowing waters in rivers and lakes but they tend to occupy the shallow inshore waters purposely for feeding and reproduction. In addition, they are known to tolerate high salinity levels, lethal temperatures, low dissolved oxygen and high ammonia concentrations which characterize perturbed ecosystems [42]. Besides high fecundities and being less habitat selective, *O. niloticus* displays other advanced success strategies such as faster growth rates and genetic dominance. The species has reportedly out competed native *O. esculentus* and *O. variabilis* from various ecosystems [43], [44]. This makes *O. niloticus* a highly invasive species that can occupy and establish in introduced areas and out-compete native species that are endemic to those ecosystems [44]; [45]. The focus on lakes Victoria and Jipe was informed by the reports from the previous studies on the introduction of tilapiines in the two lakes resulting to changes in fish composition and the lake ecology.

3.2 Translocation and Introduction of non-native species

Deliberate transfer and introduction of nonnative fish species across the biogeographical boundaries has been used as fishery management tool globally. According to [46], over 237 species have been introduced globally and more than 50 species introductions within the African continent. The Kenyan freshwater lakes, Victoria and Naivasha have so far recorded the highest number of species introductions of 6 and 7 species respectively, while other freshwater lakes such as Jipe and Baringo have only recorded at most two deliberate introductions (Table 1).

Such introductions are associated with unprecedented economic losses and ecological impacts due to interspecific competition with endemic species, and niche overlap [48]. However, not all introduced Tilapiines species have thrived in the new ecosystems. For instance, *Oreochromis spilurus niger* failed to establish in Lake Naivasha due to competition from established species, predation by *M. salmoides* and habitat alteration [49], [50]. Lake Victoria is currently dominated by introduced species, *Lates niloticus and O. niloticus*, which together with native *Rastreneobola argentea* form the mainstay of the commercial multispecies fishery [51]. Although the fishery introductions were projected to bring more economic benefits to the riparian communities, the introduction of *Lates niloticus* and four tilapia species led to decline of native species populations in Lake Victoria [11].

Table 2
Distribution, status and maturity sizes of tilapia in lakes Victoria and Jipe

Oreochromis species	Distribution and maximum known length	Reference
Oreochromis esculentus (Graham, 1928)	Native to and critically endangered in Lake Victoria; 25.3 cm SL	[46]
Oreochromis jipe (Lowe-McConnell, 1955)	Native to Pangani basin where it is critically endangered; 34.5 cm SL	[40], [46]
Oreochromis leucostictus (Trewavas, 1933)	Introduced in Lake Victoria and Naivasha basins; 32 cm TL	[46]
Oreochromis niloticus (Linnaeus, 1758)	Introduced in Lake Victoria basin; 39.5 cm SL	[46]
Oreochromis variabilis (Boulenger, 1906)	Native and presently endangered in Lake Victoria basin; 26.7 cm SL	[46]

3.3 Decline of native tilapia fisheries in Lake Victoria

Riparian communities around Lake Victoria depend on fish as the most affordable source of animal protein [52]. Before the introduction of *L. niloticus* and four tilapiines, Lake Victoria had a diverse multispecies fishery dominated by over 500 species of Haplochromines which co-existed with the native tilapiines *O. esculentus* and *O. variabilis* [11]. Between 1960s and the year 2000, remarkable ecological changes occurred in the lake attributed to the upsurge of *L. niloticus*, which directly preyed upon *O. esculentus* populations [53]. Despite the decline of native fisheries, Lake Victoria reported increased in fish landings from the introduced *O. niloticus* and *L. niloticus*, but the increase was unsustainable due to reported dwindling trends [43], [54].

The *O. variabilis* is currently red-listed by the IUCN among the critically endangered species which are on a verge of extinction from their native range in the Lake Victoria catchment following exotic introductions [38]. The *O. niloticus* is an opportunistic omnivore with a diversified feeding that exploits a wide range of food sources such as insects, algae, fish, molluscs and detritus [55]. Therefore, the proliferation of *E. crassipes* is likely to have provided additional feeding and breeding grounds resulting to increased catches of exotic *O. niloticus* during the periods of infestation [55]. Consequently, the fishery composition of Lake Victoria shifted from the dominance of native tilapiines *O. esculentus* and *O. variabilis* in early-1960s [43], [56] to *O. niloticus*. It is possible that that the displacement of *O. esculentus* to small satellite lakes such as Lake Kanyaboli, where it currently occurs as separate and isolated stocks contributed to this decline [54]. Several factors have contributed complex interactions between native and exotic tilapias, which account for the decline of native tilapiines in Lake Victoria [57]. For instance, the observed dietary overlap between adult *O. leucostictus* and *O. variabilis*, and juvenile *O. esculentus* and the three exotic tilapiines, which were introduced into Lake Victoria [58]. There is also niche overlap between *O. variabilis* and the three introduced tilapiines [11]. The declines of native species have reportedly caused disruption of food chains and nutrient cycling which have consequently accelerated eutrophication in Lake Victoria [59].

3.4 Other causes for decline of native fisheries

3.4.1 Effects of Euthrophication

Excess nutrient loading has also resulted to change in the phytoplankton community from small-sized diatoms to unpalatable large-sized Cyanobacteria, *Microcystis spp*. which sometimes produces harmful algal blooms (Lung'ayia et al. 2000). This might have reduced the food sources for *O. esculentus* that feeds almost exclusively on diatoms [57], and *O. variabilis* that feeds mainly on small sized phytoplankton [37]. The declines of *O. esculentus* and *O. variabilis* populations has been accelerated by the change of algal community from the dominance of small sized diatoms which can be manipulated by native tilapia with a small gape size to blue green algae which can only be fed by exotic *O. niloticus* [23]. Besides, the proliferation of Water hyacinth, *Eichhornia crassipes* favoured the occurance of populations of introduced *C. zilli* that feeds on the floating macrophyte over native tilapiines [44].

3.4.2 Interspecific hybridization

Increased interspecific hybridization between *O. niloticus* and the native *O. esculentus* species makes it difficult for Lake Victoria to support self-sustaining populations of native tilapia. There has been reported interspecific hybridization between *O. variabilis* and *O. niloticus* [57]. *Oreochromis niloticus* does not occur naturally with native tilapiine species and has been reported to hybridize with native tilapia due to lack of complete genetic isolation between the exotic and native tilapia [37].

3.5 Lake Jipe Ecology and fisheries

Lake Jipe fisheries sector initially supported slightly more than 5,000 people [60]. In addition, the supports a a large biodiversity and provides refugia and breeding ground for both resident and migratory birds, and has been recognized as a wetland of international importance under the Ramsar Convention [31]. The lake also supports a high diversity of wildlife that contribute significantly to socio-economic development through tourism and is protected as national reserve under the Tsavo West National Park in Kenya and

Mkomazi Game Reserve in Tanzania [61]. Despite being a highly significant ecosystem, there is a lack of uniformity in cross border management and conservationist strategies due to inadequate scientific information to support policy formulation. This is compounded by lack of integrated water resource management plan to guide largescale water abstraction for various uses such as urban, agricultural and domestic uses. Lake Jipe faces many ecosystem challenges such as accelerated runoff, increased siltation, deterioration of water quality, a collapsing fishery and altered hydrology [60]. Several hydrological transformations have resulted from the diversion of River Lumi instead of flowing into the lake. The lake riparian land and its catchment are being used for agricultural development while the waters of the drainage basin are diverted for domestic supply and expansion of irrigated agriculture.The current ecological changes are linked to lack of adequate community involvement in management and conservation of Lake Jipe ecosystem. This results to poor land use has led to degradation of the lake catchment and deterioration of water quality during erratic rains characterized by high levels of siltation and increased salinity during drought, resulting to virtual disappearance of the foating-leaved macrophytes such as the water lilies *Nympaea species* and the pigmy Geese [62]. Due to decline in the lake water depth, a large proportion of the inshore area is dominated by emergent macrophytes such as *Typha domigensis* and a decrease of the area of open waters [62]. Thus, plant succession has been observed by disappearance of water lilies and dominance of *Typha sp.* as the main wetland plant dominating the inshore areas. Catchment degradation has been aggravated by unsustainable farming activities resulting to siltation.

3.6 Challenges to Lake Jipe Fisheries

In contrast to *O. niloticus* and *O. esculentus*, the Kenyan Coastal native *Oreochromis jipe* species is limited in distribution to a native range of less than 100 km² in the Pangani Catchment of Kenya and Tanzania and makes marginal contributions to livelihoods [38]. *Oreochromis jipe* and *O. esculentus* have reportedly a high potential for commercial aquaculture because of many characteristics shared with *O. niloticus* and being the most important species in terms of size [46]. The back side of sharing common characteristics with *O. niloticus* is increased rates of inter-specific hybridization which makes it difficult for lakes Victoria and Jipe to support self-sustaining populations of *O. jipe* and *O. esculentus* respectively [63]. Nevertheless, the two native species currently coexist with exotic *O. niloticus* in Lake Jipe. The *O. jipe* has been reportedly displaced and hybridized by both *O. niloticus and O.esculentus.* For instance, [64] reported that *O. jipe* species was displaced from Lake Jipe by *O. esculentus*, which invaded the lake from Nyumba ya Mungu reservoir downstream. In addition to *O. esculentus* invasion, siltation led to the proliferation of emergent macrophytes such as *Typha domingensis* and *Cyperus papyrus* which culminated into the loss of inshore habitats, also contributing to remarkable decline and subsequent abandonment of the *O. jipe* fishery [31].

4. Conservation Strategies For Tilapia Species

The decline of native fisheries biodiversity has been wrought by many factors, which are a composite of invasion by exotic species and ecosystem degradation. Consequently, the tilapiines *O. esculentus* and *O.*

jipe are currently red-listed by the International Union for Conservation of Nature (IUCN) as critically endangered species [46], [40]. Despite the adoption of bottom-up approaches towards fisheries management, *O. esculentus* and *O. jipe* are currently fished beyond the biologically sustainable limits using the illegal small-meshed and .semi-standard fishing gears. The summarized process of sustainable management for native tilapia fisheries is shown in Fig. 2. The capture of immature fingerings using these gears allows limited possibilities for continuous recruitment. However, the bottom – up participatory fisheries management which involves the Beach Management Units (BMUs) is still pivotal towards restoration of overfished stocks [65]. Additional strategies are still needed to restore the lakes' ecological integrity for the conservation of native tilapia fisheries biodiversity in the two inland lakes [66]. For instance, a shift in management paradigm towards "sustainability thinking" is needed to reduce overexploitation of lacustrine fisheries resources, and eradicating lake degradation practices that are ecologically detrimental to native fisheries. *Oreochromis jipe* and *O. esculentus* require a low input system for their captive breeding and production because they are predominantly herbivores, which make them potential aquaculture candidates [10], [54]. Therefore, successful domestication and culture of these species presents immense opportunities for aquaculture growth and development in Kenya and Tanzania. In addition, there should be a transfer of localized ecosystem conservation initiatives which are geared towards sustainable utilization of the lake the fisheries, such as the public-private partnership, which has been successfully used to mitigate catchment degradation in Lake Naivasha [67]. These initiatives promote collaborative efforts among the stakeholders during implementation of locally-tailored large scale projects aimed at improving the water quality and ecological integrity of the inland lakes [19].

4.1 Lake restoration strategies

Fishery introductions have had both negative and positive impacts on aquatic ecosystems, but are to some extent justifiable because of increased fish landings. To achieve long-term sustainability in food and nutrition security, the biodiversity of red-listed species such as *O. jipe, O. variabilis* and *O.esculentus* should be addressed. The *O. esculentus* and *O. jipe* species have displayed good aquaculture potential that makes them good candidates for aquaculture introductions [10], [68]. Restoration of the ecological integrity of Lake Jipe requires the integrated and harmonized conservation strategies. This can be achieved through the incorporation of catchment-based natural resource management (CB-NRM) strategies into the national and local planning and decision-making processes. The implementation of these strategies however requires regional cooperation among various governmental and non-governmental institutions and also between the Kenya and Tanzania governments. The CB-NRM aims at restoration of ecosystem integrity to maintain the structure and functioning of the lake ecosystems that sustains the provision of ecosystem goods and services. This can be achieved through the successful trans-national collaborative efforts, and bilateral resource agreements which will provide guidance to funding agencies. A joint Commission and several management committees should be put in place to coordinate various projects, activities and catchment conservation and restoration strategies. These can be successfully implemented through the East African Community (EAC) and non-governmental organizations (NGOs), such as the International union for the conservation of nature (IUCN) and World Water Fund (WWF).

5. Conclusion

The remarkable decline of native tilapia fisheries in lakes Victoria and Jipe has been attributed to overfishing, environmental degradation and the introduction of invasive species into the lakes. However, complete assessment of the overall ecological and economic impact of the introduced species requires another comprehensive study focusing on many aspects of the two fisheries. Nevertheless, the decline and virtual disappearance of *O. jipe* and *O. esculentus* from their native ecosystems has been exercerbated by the introduction of non-native fisheries. Moreover, high levels of degradation in lake ecosystems have occurred due to euthrophication, pollution and siltation caused by human activities. Due to its superior characteristics, *O. niloticus* has been introduced in lakes Victoria and Jipe mainly for argumentation of native fisheries and currently coexists with both *O. esculentus* and *O. jipe* in Lake Jipe. Although being genetically superior to *O. jipe*, *O. esculentus was* reportedly displaced to small satellite lakes in Lake Victoria basin by *O. niloticus.* Small native tilapiines such as *O. esculentus* and *O. jipe* have been reported to exhibit slow growth rates and low fecundities, hence cannot withstand heavy artisanal exploitation and competition from highly invasive species such as *O. niloticus*. As a result of complex interactions, overfishing, competition and hybridization between *O. niloticus* and the native tilapiines, several ecological disruptions have occured contributing to the decline and virtual disappearances of both *O.* jipe and *O. esculentus* species from their native ecosystems. Managing the increasing invasive species populations in the two lakes poses a challenge to conservation, management and restoration of fisheries.

6. Recommendation

There is need to control fishing effort, pollution and conserve the lake catchments from degradation by increasing anthropogenic activities. In addition, there should be assessment of ecological impact of tilapia species before their introduction into new ecosystems and all aquaculture expansion should focus on areas where the *O. niloticus* species has already been introduced. Further research work is needed to assess the possibility of natural hybridization between *O. niloticus* and native tilapia in the introduced areas. This review also suggests the need for scientific and policy interventions which considers fisheries sustainability in the wider perspective of future demographics, land use changes and climate change scenarios.

Declarations

Author Contributions

The corresponding author conceptualized and supervised writing of this paper. All the authors contributed equally in the formal analysis, visualization, verification of information, preparation and writing of the original draft, as well as review and editing of the final draft before submission.

Competing Interests

Authors declare that they have no competing personal, financial or professional interests that can unduly influence the outcome of this publication.

Data availability

No field or experimental data are associated with this review article

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Figures

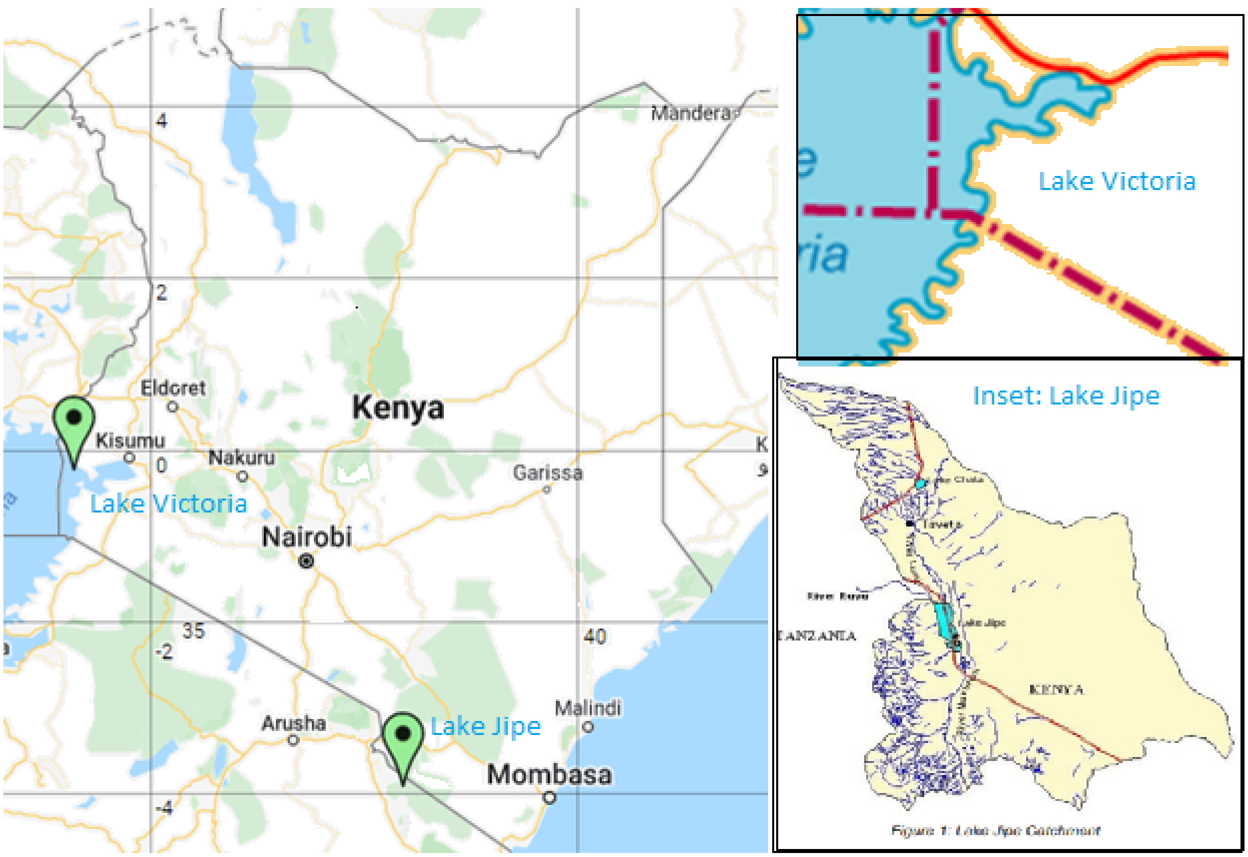

Figure 1

Location of lakes Victoria and Jipe in Kenya.

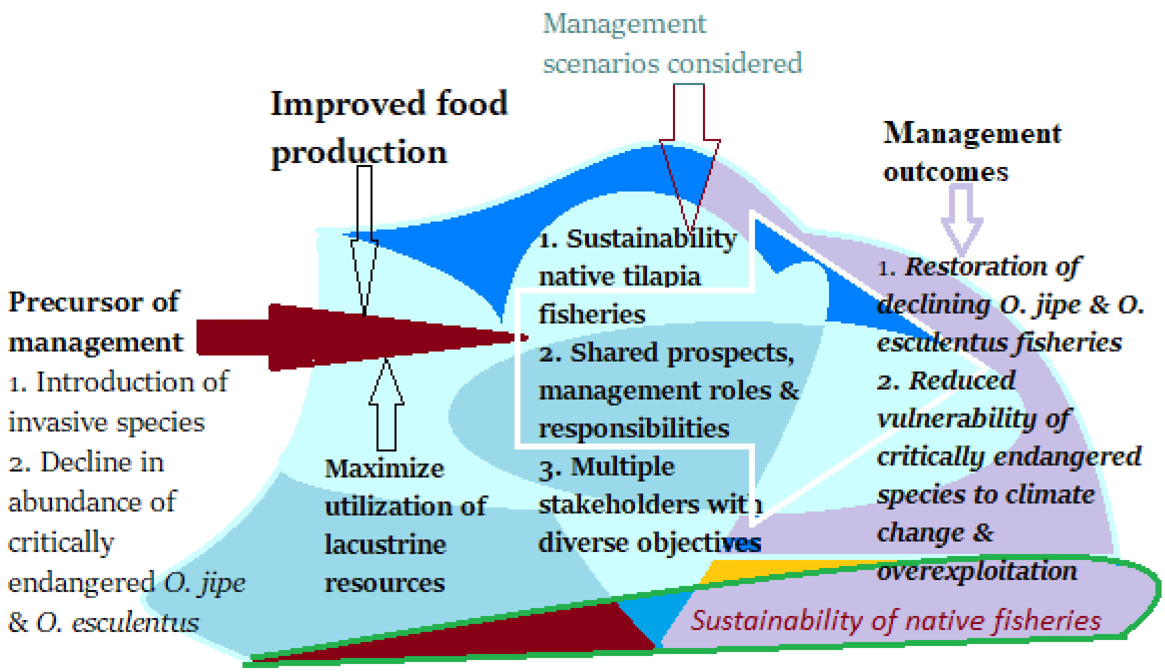

Figure 2

considerations for sustainable management of native tilapia fisheries in lakes Victoria and Jipe