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Community-Managed Fish Sanctuaries for Freshwater Fishery Biodiversity Conservation and Productivity in Malawi

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Abstract: Key fish breeding and other biodiverse areas in Malawian lakes are under threat from illegal fishing, the siltation of key breeding areas (due to deforestation-induced soil erosion), and the clearing of shoreline aquatic vegetation. Freshwater protected areas, also called sanctuaries, have the potential to support the restoration of degraded aquatic environments and protect fisheries' biodiversity. In Malawi, community-managed fish sanctuaries have been established by beach village committees (BVCs) throughout Lake Malawi, Lake Malombe, Lake Chilwa and Lake Chiuta. The sanctuaries were established to conserve exploited stocks, preserve biodiversity, and enhance fisheries' yield. The BVCs are aligned with local decentralized village development committees linked to District Councils. Together, they constitute a defragmented decentralized ecosystem-based management of fishery resources. A monitoring study was conducted in sanctuaries in the four lakes during the wet and dry season over three years (2016–2019). The monitoring was carried out to evaluate the sanctuaries' biological performance. The results showed that community-managed sanctuaries contributed to a 24% increase in the total number of observed species. The Shannon Diversity Index increased from an average 1.21 to 1.52. Small and mid-size (<50 ha) sanctuaries showed a higher performance improvement than large (>50 ha) sanctuaries. This is likely due to multiple factors, including a higher level of fish movement and the greater ability of communities to surveil and enforce smaller sanctuaries. The participation of communities in monitoring enhanced the demonstration effects of sanctuaries. This, in turn, encouraged communities to expand the number and size of the sanctuaries. The biological performance results indicate that community-managed freshwater sanctuaries can be used to protect and restore fish biodiversity in freshwater lakes in Africa. Linking the BVCs to defragmented decentralized structures ensures that the interconnectedness between ecosystem uses, including forestry, agriculture, and tourism, which impinge on fish productivity, are addressed holistically.

Keywords: freshwater protected areas; defragmented management; fish biodiversity

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1. Introduction

Malawi is in the unique position of hosting over 14% of the world's total biodiversity in freshwater fish species. More importantly, 90% of the 800 species of fish that are found in Malawian waters are unique and endemic to Malawi. According to the International Union of the Conservation of Nature (IUCN) Red Book [1,2], the fish endemic to Lake Malawi are all considered 'vulnerable' because they occur nowhere else in the world. Any threats to Lake Malawi's fishery ecosystems could contribute to the eradication of these fish. Moreover, habitat degradation; illegal, unregulated, and unreported fishing (IUU); overfishing; and climate change contribute to declining fish catches, and they pose a significant risk to the sustainability of fisheries' biodiversity and productivity. In Malawi, the uniquely biodiverse lakes are under threat from illegal fishing, the clearing of shoreline aquatic vegetation, and the siltation of key breeding areas caused by deforestation induced soil erosion.

Freshwater protected areas, also called sanctuaries, have been proposed as a strategy for restoring degraded aquatic environments and protecting fisheries' biodiversity. Marine protected areas (MPAs) and freshwater protected areas (FPAs) are technical measures that are implemented by fisheries managers to restore and conserve fisheries' biodiversity [3].

MPAs and FPAs can be divided into six categories, which represent a continuum from stricter protection to regimes designated for sustainable use [3]. A fish sanctuary is a type of protected area where a portion of water is temporarily or permanently protected by reason of their unique physical and biological significance and managed to enhance biological diversity and provide a haven for fish populations to feed, breed and grow. Community-based protected areas are widely promoted in Africa to address gaps in biodiversity conservation [4]. Fish sanctuaries can be formally established and justified based on international conventions (e.g., RAMSAR and the World Heritage Sites); state laws; district bylaws; traditional sanctions; BVC bylaws; and other binding measures.

Based on the success of MPAs, protected areas are increasingly being promoted among freshwater fisheries managers. Most reservoirs and river basins threatened by biodiversity loss have peripheral areas, where human pressure is low. These are areas that have preserved populations and communities of freshwater fish (e.g., Ref. [5]). Research has shown that installing sanctuaries/reserves in such key aquatic systems can re-establish fish populations and increase both abundance and species diversity, but in order to protect these rich habitats, one must first identify and characterize them [6–9]. The first freshwater reserve in the world was the Lake Malawi National Park and World Heritage Site, established in Lake Malawi in 1984. Other FPAs in Southern Africa include the Mahale Mountain Park on the shores of Lake Tanganyika [7]. In Malawi, community-managed fish sanctuaries, established through the participation of local communities and fisheries stakeholders, are used in combination with nationally established FPAs for integrated fisheries conservation [1,10,11]. The goal of applying a participatory sanctuary establishment process is to convince communities that fish sanctuaries will benefit them in long term, mainly through the increase in fish production and restoration of lost habitat. A secondary goal is to empower communities by giving them the opportunity to own the process. Successful community-based fish sanctuaries require the restriction of some or all fishing activities within designated areas, governed and enforced by local community rules and norms.

There are several different approaches for establishing freshwater protected areas, ranging from developing new and specific-purpose legislation to minor modifications and continued use of existing protected area legislation. MPAs have commonly been established under fisheries, forestry, and wildlife management legislation. Decentralized management also allows them to be established via local by-laws. Finding the right approach requires a detailed understanding of a country's cultural context and legal processes. The Malawi Government has adopted the ecosystem approach to fisheries management (EAFM) within which the concept of participatory fisheries management is applied to manage fisheries resources [11]. Participatory fisheries management is practiced under a decentralized fisheries management structure with local fisheries management authorities operate as fisheries associations (FAs) at the district level and beach village committees (BVCs) at the village level. The local fisheries management structures are linked to defragmented decentralized bodies, such as the district council, and area and village development committees (Figure 1). Linking the BVCs to defragmented decentralized structures ensures that the interconnectedness between ecosystem uses, including forestry, agriculture, and tourism, which impinge on fish productivity, are addressed holistically. It is within this context that community-managed fish sanctuaries are being promoted to enhance fisheries' biodiversity conservation and productivity.

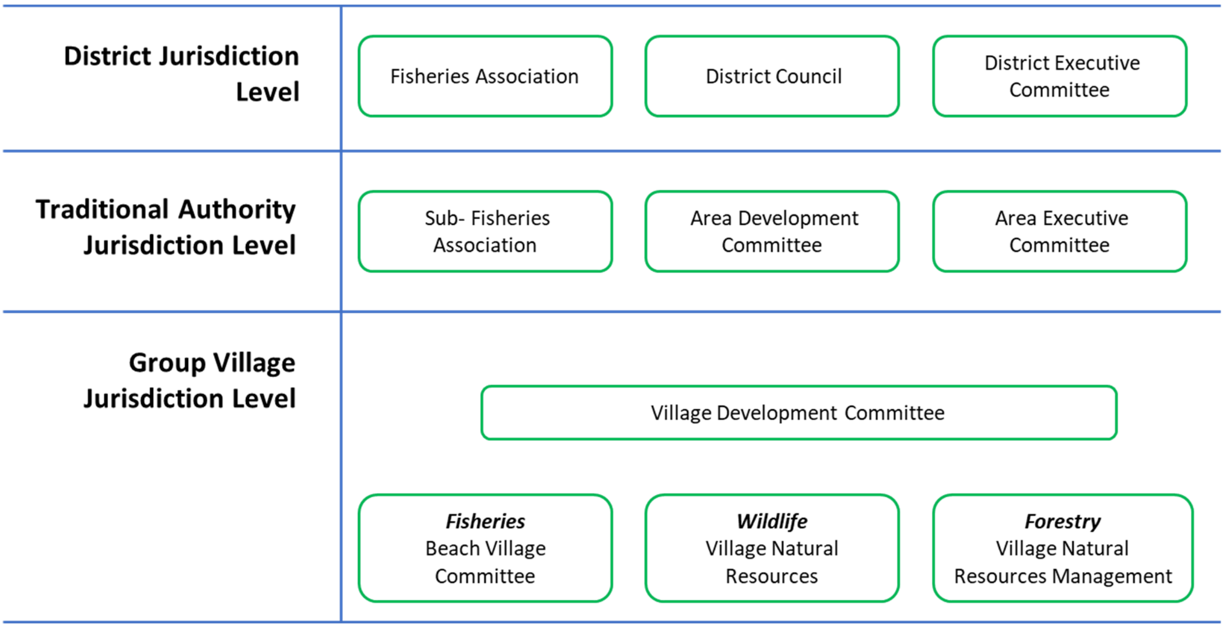

Figure 1. Malawi's decentralized local government structure showing linkages between fisheries and other natural resources management structures.

Community-based fish sanctuaries can be useful tools for FAs, BVCs, and other local management bodies because they involve a participatory process when determining rules and responsibilities that apply to local resources [12]. The process instills the collective management of natural resources. Hence, when the circumstances are right, community-based fish sanctuaries can encompass Elinor Ostrom's eight design principles. These characterize robust, self-organized institutions that are able to create collective action, which in turn contribute to sustainable resource use [13,14]. Meant as a guide rather than a blueprint, the design principles are (1) clearly defined boundaries and agreements on who is entitled to use the common property resource, (2) congruence between rules and local conditions, (3) collective choice arrangements, (4) monitoring, (5) graduated sanctions, (6) conflict resolution mechanisms, (7) a minimal recognition of rights to organize, and 8) the application of a nested governance approach that connects community management with higher level governance systems. Ostrom's design principles have been used as a framework to evaluate the performance and success of MPAs, e.g., Refs. [15,16].

Fish sanctuaries are usually established with the goal of restoring or repairing the fisheries and their habitats in areas known to have important ecological functions. Sanctuaries help control fishing effort, protect breeding and feeding grounds and juvenile fish nursery areas, and guard against any form of unregulated fishing—thereby ensuring that a sustainable supply of fish repopulates the main fishery and benefits the local populations. Community-based fish sanctuaries can also foster ecosystem stewardship. The concept of environmental stewardship [17] expands upon socio-economic models of regulatory compliance, which argues that compliance depends on the expected penalty, the perceived illegal gains, and leadership and social influence that in turn inspire people's moral obligation to do what is fair and appropriate [18]. The environmental stewardship concept goes beyond focusing on compliance to acknowledging that fishing communities can adopt sustainable practices—even in cases where there are no formal rules—when they believe that it is the right thing to do [19–21].

This paper presents a case study of the establishment of community-managed fish sanctuaries in Malawi. The paper assesses the performance of community-based fish sanctuaries by tracking the temporal performance of the sanctuaries in terms of fish species composition and diversity. It further examines the contribution of defragmented decentralized governance on the sanctuary performance and provides recommendations for the upscaling and adoption of sanctuary establishment in other African great lakes.

2. Materials and Methods

2.1. Establishment of Sanctuaries

Participatory rapid appraisals were conducted using an ecosystem threats opportunity assessment (ETOA) approach. The assessment identified biodiversity hotspots, primary biodiversity threats, drivers, and stressors. It also identified opportunities to address the primary threats [19]. Through a consultative process, communities identified traditionally managed permanent or seasonal closed areas that could be revived and used to protect and restore fish biodiversity in identified hotspots. New sanctuary sites were also identified and established through a consultative process that included adjacent communities. The participatory process aimed to increase voluntary compliance and sustainability and improve buy-in among fishermen. To the extent possible, the sanctuaries were established in biodiversity hotspots, such as rocky areas, inlets, and areas with submerged aquatic vegetation, which are important breeding and nursing grounds for fish. All sanctuaries were GPS referenced in collaboration with fishing communities and the total hectarage of each sanctuary was calculated based on the GPS measurements.

2.2. Sanctuary Performance Monitoring

A monitoring plan was set up to evaluate the management, biological, and governance performances in the community-based sanctuaries established in Lake Malawi, Lake Malombe, Lake Chilwa, and Lake Chiuta. Monitoring was conducted by project staff and scientists of the Monkey Bay Fisheries Research Station (MBRFS) in collaboration with the BVCs. Socio-economic, management and governance indicators were evaluated in a separate monitoring program, which is not covered in this paper.

A total of 26 randomly selected community-managed sanctuaries (Table 1) were monitored twice per year (rainy and dry season) over a three-year period from 2016 to 2019. A baseline monitoring survey (S01-16) was conducted in December 2016. The monitored sanctuaries were randomly selected in five areas: the south-east arm (SEA) and south-west arm (SWA) of Lake Malawi, Lake Malombe, Lake Chilwa, and Lake Chiuta. Follow up monitoring surveys were conducted in September 2017 (S01-17), February 2018 (S01-18), August 2018 (S02-18), and February 2019 (S01-19). Each monitoring event included measuring the species diversity, fish size distribution, and abundance. The 2019 monitoring event included comparing biodiversity and abundance inside and outside seven sanctuaries. Four random samples were taken inside and outside the sanctuaries using the same gear and within a short time (less than four hours).

Table 1. Fish sanctuaries by district and water body in Malawi.

	SWA Lake Malawi	SEA Lake Malawi	Lake Malombe	Lake Chilwa	Lake Chiuta
Sanctuaries	Mfula Bulangeti Chisenga 1 Chisenga 2 Mbeya Kasankha Katole Matekwe Simoni	Chiwalo Matuwi Nkhudzi Bay Mvera Chindongo Michesi Bolera Chole Mombo	Chisumbi Chiwaula Kambulire Likala	Kankhandwe	Lifune Aduwa Njerwa

2.3. Sampling Protocol

Sampling in all sanctuaries was conducted in fixed stations selected by the team in consultation with local fishermen. Standard open water seine nets with 8 mm mesh size in the bunt and a headrope length of 70 m for Lake Malawi and 120 m for Lake Malombe were used to collect fish samples inside and outside of the sanctuary. Both the inside and outside sampling sites were located 30 m from the perimeter fence. The nets, which followed the measurements used by local fishermen, were constructed for this survey. In each sanctuary, three net hauls were taken inside and outside of the sanctuary and as close as possible to the geo-referenced stations sampled during the baseline survey (S01-16). After each haul, the catch was sorted and identified by species, counted, and measured (numbers and weight). Fish that could not be identified to the species level with certainty were recorded at the lowest possible taxon. Length frequency measurements were taken at the nearest millimeter using a measuring board. After the identification and measurements were completed, the fish were kept in holding hapas (a hapa is a fixed net enclosure, like an inverted mosquito net. It is made from polyethylene netting with joints in nylon thread, double stitched to prevent splitting) to avoid recapturing the fish. Once the assessment had been completed, the fish were returned to the water. In addition, GPS coordinates were recorded for the perimeter of each sanctuary, the corresponding control areas, and the swept area. These data were used to calculate hectares, productivity, and the fish biomass per hectare for each sanctuary.

2.4. Data Analysis

Species richness was computed as a measure of biological biodiversity. It is a measure of the number of species captured in each sanctuary during the sampling. The species richness was calculated using the Menhinick's index [22]. The diversity of species in each sanctuary depends not only on the number of species found, but also their abundance and distribution. Species evenness refers to how close in numbers each species is in an environment. The combination of richness and evenness measures the diversity in each sanctuary. Fish diversity was calculated using the Shannon Diversity Index (H). Biomass estimates were made using the swept-area method [23]. The swept area was considered a circular area when using seines, while for beach seines, a half circle was considered an area. A preliminary analysis of the biomass estimates showed that the biomass estimates had a high coefficient of variation of about 20% during the survey. This is well below the acceptable norms for nearshore surveys of finfish. Therefore, the biomass estimates were considered nonoptimal, and they were not used to evaluate sanctuary performance.

The sanctuary performance evaluation was carried out using a comparative analysis of fish species diversity and richness among sanctuaries within and between lakes using one-way analysis of variance (ANOVA). Unplanned comparisons between pairs were examined using the paired *t*-test and the Tukey–Kramer HSD (honestly significant difference) test for ANOVA ($\alpha = 0.05$).

2.5. Geographical Location

The community-managed sanctuaries selected for monitoring were those randomly selected and assessed during the baseline survey (S01-16), plus six new sanctuaries established in 2017 (Figure 2). The sanctuaries monitored in Lake Malawi (both SEA and SWA) covered 500.54 ha while the sanctuaries in Lake Chiuta, Lake Chilwa and Lake Malombe covered 116.2, 52.88 and 41.54 ha, respectively.

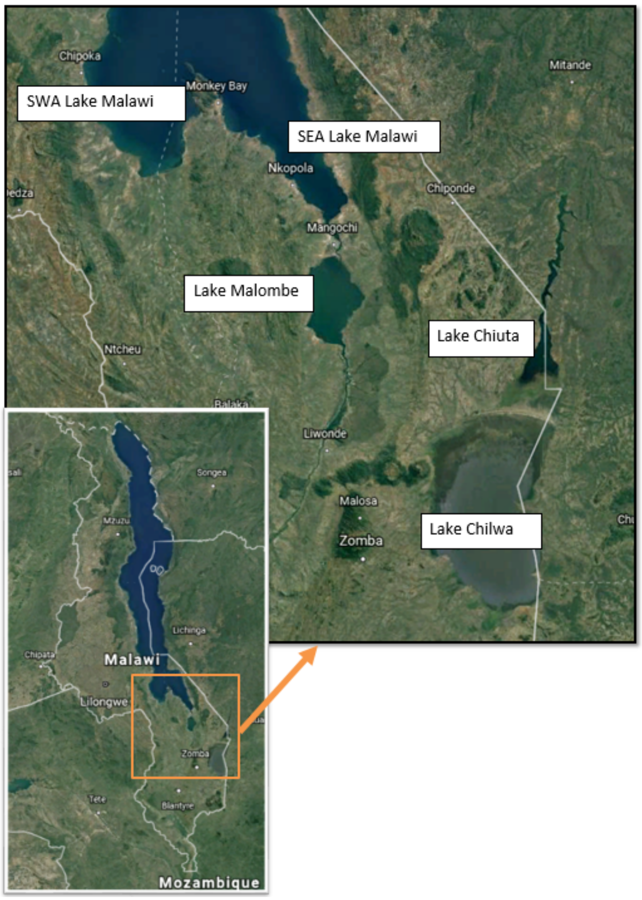

Figure 2. Community-managed sanctuaries by waterbody in Malawi.

2.6. Effect of Governance on Biological Performance of Sanctuaries

Results from a community performance index (CPI) of fisheries comanagement of four lakes in Malawi [10,24] were used to assess the quality of the BVCs governance of each sanctuary. CPI is a tool that uses four attributes of service provision as domains against which to assess and rate the performance of community structures. The four CPI domains are quality of service (effectiveness), relevance, resource mobilization (sustainability), and efficiency. Data from the Malawi Annual Fisheries Frame Surveys and location of beaches to major roads were also used to establish the fishing effort and market access. This represents the relative fishing pressure that the various sanctuaries were subjected to. The CPI study found that sanctuaries that are exposed to high fishing pressure are likely to underperform when BVCs are weak and unable to effectively enforce by-laws and fisheries regulations [10,24].

3. Results

3.1. Biological Performance

A total of 56 sanctuaries covering 1022 ha were established between 2016 and 2019. Twenty-one sanctuaries were established with the active involvement of an externally funded project while 35 sanctuaries were established independently by local communities who saw the success of the initial 21 sanctuaries. The areas designated for sanctuaries varied from 1.2 ha to 274 ha. During the analysis, the sanctuaries were divided into three categories (small (<10 ha), medium (11–50 ha) and large (>50 ha)). The Lake Malawi sanctuaries showed the highest species richness, with a total of 39 species, followed by Lake Malombe with 31 species (Figure 3).

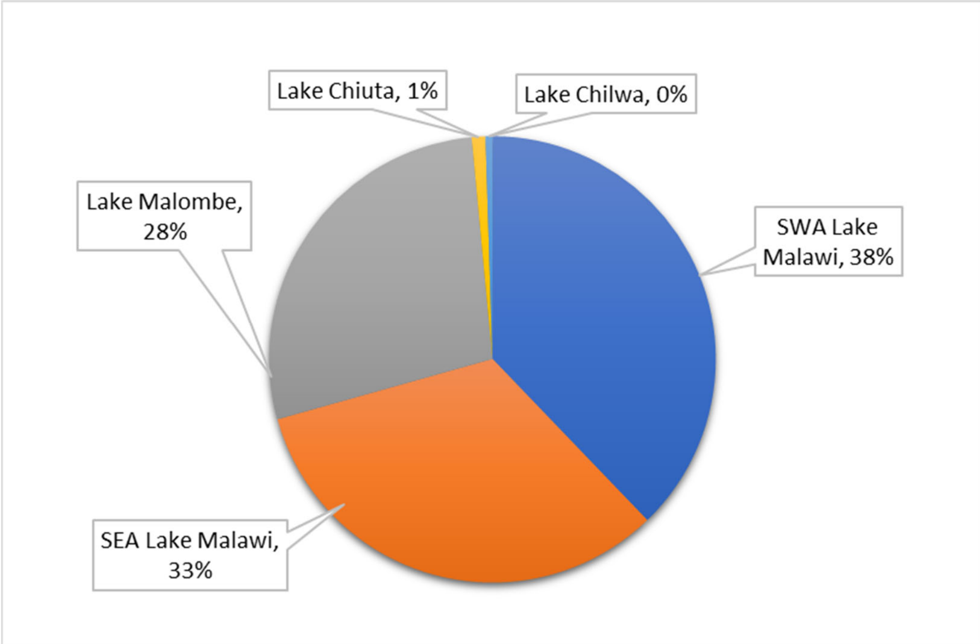

Figure 3. Contribution of waterbody to total species richness (%).

The two smaller lakes, Chilwa and Chiuta, are known to have lower richness and the survey teams only encountered two and six species, respectively, in those lakes (Figure 4). The species richness was higher in SEA compared to the SWA and Lake Malombe. However, there was a large degree of overlap between the species in the three areas.

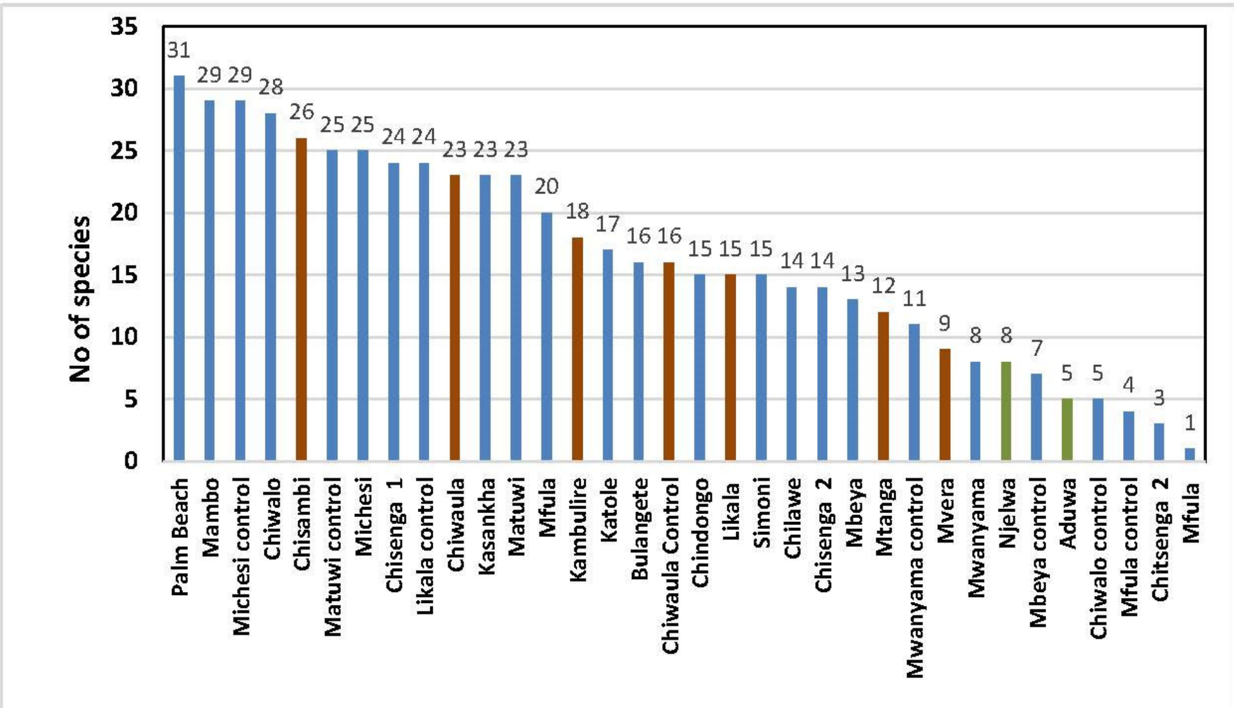

Figure 4. Species richness by monitored community-managed sanctuary in Lake Malawi (blue bars), Lake Malombe (brown bars) and Lake Chiuta (green bars).

A total of 85 species were collected by the survey teams over four years. Three major species represented the bulk of the catch in all the lakes. They belonged to the family of Cichlidae (*Protomelas similis* (Regan, 1922), *Copadichromis chrysonotus* (Boulenger, 1908)), and Cyprinidae (*Engraulicypris sardella* (Günther, 1868)). The number of species increased by 24% from the baseline to the 2019 survey. In addition, the endangered (IUCN Red List (The Red List provides scientifically based information about species' survival, promotes public education about biodiversity, influences governmental policies, and offers advice about conservation efforts. A species categorized as vulnerable will probably become endangered in the near future due to survival threats such as habitat loss and destruction. The IUCN considers an endangered species to be likely to become extinct. This is the second most serious conservation status for wild plant and animal species) *Opsaridium microlepis* (Günther, 1868) was recorded in seven sanctuaries (four in Lake Malawi and three in Lake Malombe) while the vulnerable (IUCN Red List) *Opsaridium microcephalum* (Günther, 1864) were recorded in three sanctuaries (two in Malombe and one in Lake Malawi). In 2017, *O. microcephalum* (Günther, 1864) was recorded in only three sanctuaries, namely Kabuthu Sanctuary (Lake Malawi) and in Chisumbi and Likala Sanctuaries in Lake Malombe. In addition, specimens of *Oreochromis lidole* (Trewavas, 1941), listed as an endangered species under the Red List, were sampled in the Chia Lagoon (James Banda, pers. Comm) and *Labeo mesops* (Günther, 1868) were observed by communities in sanctuaries in Lake Malawi and Malombe.

The results of trends in fish biodiversity measured by the biodiversity index H are summarized in Table 2 below.

Table 2. Summary of sanctuary fish biodiversity (H) performance trends over 4 years and description of ecological and governance (assessed by CPI) and social–economic characteristics of the sanctuaries.

Biodiversity Index (H) Trend	No of Sanctuaries (% of Total Monitored)	Biodiversity Index (H) Range	Ecology and Geography	Governance and Socio-Economic Characteristic
Increasing	10 (50%)	0.85–1.96	High emergent and submerged vegetation density, rocky habitats, lagoons and colocation in national parks	Strong BVCs with good linkages with environmental conservation groups, and BVCs undertaking patrols
Declining	3 (15%)	2.59–1.05	Sandy and rocky bottoms, generally large sanctuaries ranging from 26 to 90 ha	BVCs undertaking patrols, high fishing effort due to proximity to large fishing villages and main roads, and inadequate patrols due to large size of sanctuaries
Stable	3 (15%)	1.57–2.12	Sandy and rocky habitats, large sanctuaries ranging from 21 to 274 ha	High fishing effort due to proximity to large fishing villages and main roads, and inadequate patrols due to the large size of sanctuaries and weak BVC governance
No trend	4 (20%)	1.52–1.74	Sandy and rocky habitats with aquatic vegetation, some low species diversity (Lake Chiuta)	High fishing effort due to proximity to large fishing villages and main roads, and strong BVCs undertaking patrols linked with environmental conservation committees

Figure 5 presents the results of fish biodiversity index (H) for combined means and standard errors for biodiversity and abundance values inside and outside of the monitored sanctuaries.

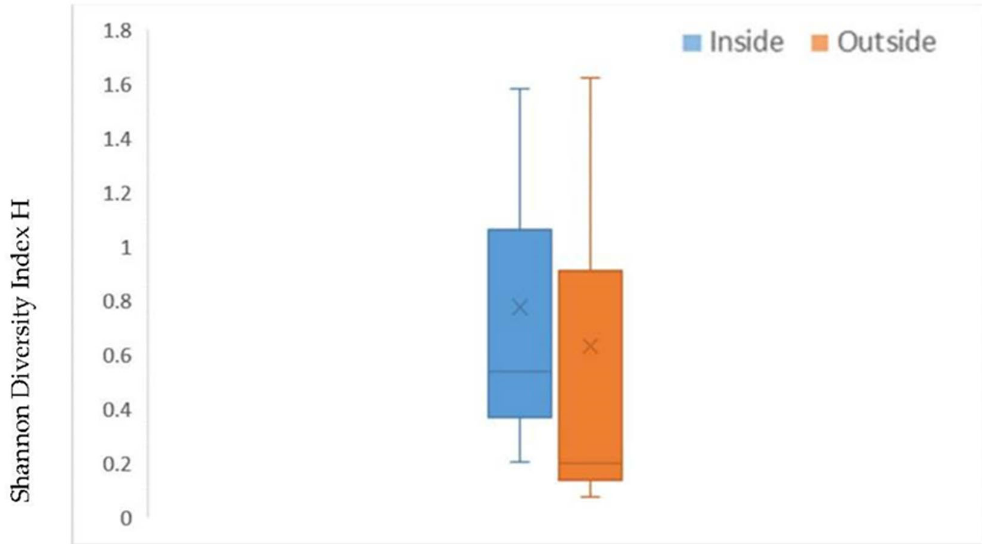

Figure 5. Box plot showing maximum, minimum and median Shannon diversity index for fish biodiversity inside and outside of the sanctuaries.

The results show a slight but not significant (ANOVA, P = 0.60; $F_{(1, 14)} = 0.276$) increase in biodiversity and abundance between the protected areas and fished areas outside the sanctuaries. The variance of the mean biodiversity and abundance was high, which may be attributed to the fact that the sanctuaries were in different lakes and habitats. This meant that, as shown in Figure 4, the sites had a wide range of species richness, where sandy areas and sites located in Lake Chiuta had low species richness and sampling sites located in rocky habitats and submerged aquatic vegetation had higher biodiversity. This indicates that the habitat type is a key determinant for biodiversity for both sanctuaries and unprotected areas. The similarity of fish biodiversity inside and outside the sanctuaries may be attributed to a spillover effect. This is substantiated by the finding that the abundance and diversity of outside areas decreased as the distance from the sanctuaries grew other findings, including the reappearance of endangered species and an increase in the number of fish species sampled inside sanctuaries, indicating that they have biodiversity conservation value.

3.2. Governance

The sanctuaries' ability to conserve and restore biodiversity and productivity depends on the habitat characteristics, the fish population numbers, and the BVCs' ability to enforce fisheries regulations and by-laws. The sanctuaries in Malawi fall under IUCN's protected area category IV—habitat or species management area. All the sanctuaries covered in the monitoring effort were managed by BVCs that had been trained in the six policy steps of fisheries comanagement. As part of the capacity development effort, they had undertaken resource assessments, developed management plans and by-laws, and signed management agreements with the government of Malawi. The latter provides the BVCs with use rights that enable them to manage the fishery on behalf of the Malawian government. The BVCs and FAs are federated with their respective decentralized local government structures. This links village and association-level fisheries management plans to natural resource management efforts undertaken by other sectors, including agriculture, forestry, and wildlife. This in turn reinforces habitat preservation by, for example, connecting the sanctuaries to restrictions to riverbank cultivation, the rehabilitation of riverine vegetation, bans on the harvesting of emergent aquatic vegetation and the conversion of vegetated lakeshore areas to agriculture and tourism. BVCs undertook regular self-financed patrols to enforce community by-laws and fisheries regulations. Some patrols led to the confiscation of fishing gears from artisanal fishermen and commercial fishers. However, BVC reported that they did not have adequate resources and equipment to demarcate and patrol the large sanctuaries. As a result, the large sanctuaries were prone to illegal fishing by commercial and artisanal fishers. There were conflicts in the management of sanctuaries between BVCs and artisanal fishers on one hand and BVCs and commercial fishers on the other.

4. Discussion

Results of the sanctuary monitoring program in Malawi demonstrate that community-managed protected areas can be used as an ecosystem-based fisheries management tool for restoring fisheries' biodiversity and improving the productivity of the aquatic ecosystems of inland lakes. The increase in the number of species over the four-year period was due to the expansion of the number and size of sanctuaries from the baseline of about 700 hectares in 2017 to more than 1000 hectares by 2019. BVCs expanded and added sanctuaries on their own initiative in 2017 and 2018 as they observed that the protected areas had a positive impact on fish resources. These results corresponds with the findings of Emmanuel et al. [7], whose study concluded that freshwater protected areas can be an important tool in conserving fish resources in Lake Tanganyika.

The assessment observed that fish abundance and diversity were, on average, only slightly higher in the monitored sanctuaries than in unprotected areas. However, the abundance and diversity decreased as the distance from the sanctuaries grew, which indicates a spillover effect in non-protected areas situated near sanctuaries. Hence, the spillover effect may have skewed overall calculations of abundance and diversity in outside areas. The presence of endangered species that are on the IUCN Red List, including *Opsaridium microlepis* (Günther, 1868), *Oreochromis lidole* (Trewavas, 1941), and *Labeo mesops* (Günther, 1868) and those classified as vulnerable (e.g., *Opsaridium microcephalus* (Günther, 1864)), demonstrate that the sanctuaries can contribute to the recovery of species that had been decimated by overfishing and habitat destruction.

The sanctuaries with the highest species richness were generally situated in rocky habitats. These areas also recorded higher fish density than sandy habitats. Local communities observed that they found more fish in areas with a high abundance of submerged and emerging aquatic vegetation, river inlets/outlets, and shallow and rocky areas. The monitoring and community feedback corroborate the results of earlier participatory resource appraisals [19,25] and other research [2,26], which identified and characterized rocky areas, inlets, and areas with submerged and emerging aquatic vegetation as habitats of critical biodiversity.

The involvement of communities and traditional authorities in the planning, establishment, management, and monitoring of the community-managed freshwater protected areas led to the rapid adoption of sanctuaries as a tool for enhancing fisheries' biodiversity conservation and productivity. The participatory process follows Ostrom's [14] third common property resource management design principle—collective-choice arrangements. Through participatory monitoring, BVC members and other community leaders observed that the sanctuaries contributed to habitat and fisheries biodiversity restoration within a time frame of less than two years. This encouraged the BVCs and community leaders to expand individual sanctuaries and create new ones.

Local fishermen primarily value sanctuaries from an economic perspective, expecting to see an increase in fish abundance, which in turn has the potential to increase their catch and income. Involving local fishermen in the monitoring activities, which is in line with Ostrom's fourth design principle—monitoring—allowed them to observe positive trends, which in turn increased their ecosystem stewardship and broader community involvement in and acceptance of sanctuaries as an EAFM tool. Walmsley [27] observed that community involvement in the management of sanctuaries, including the enforcement of regulations, was related to positive ecological trends in sanctuary areas. He further observed that wider community support for sanctuaries was facilitated by the proactive involvement of small discrete cohesive communities. Working with discrete and cohesive communities corresponds with Ostrom's [14] first design principle of having clearly defined geographic boundaries and specificity as to who is entitled to use the resource, because it brings clarity to what is being managed and for whom.

Fishing, tourism, forestry, and agricultural activities directly interact with fisheries in a linked socio-ecological system [28]. Together, the sectors involve extractive and interactive activities that contribute to overfishing; soil erosion resulting in the siltation and turbidity of the lake; chemical and organic pollution; the loss of access to land and beaches; and habitat loss. The mix of activities and their impacts exacerbate the negative impacts on fisheries ecosystems and biodiversity [28]. Hence, BVCs that manage community fish sanctuaries must have an organizational and governance structure that enable them to work with other decentralized local government committees to holistically address these ecosystem-wide impacts. This is in line with Ostrom's eight design principles of applying a nested governance approach.

In this study, the performance of sanctuaries under the jurisdiction of different BVCs was highly variable. The variability was partially due to differences in the level and quality of protection, monitoring, and governance by the BVCs. The study did not assess the relationship between governance quality and sanctuary performance. However, a qualitative analysis showed that sanctuaries that were established in nonsuitable habitats, such as sandy areas, and those where BVC governance was weak, performed poorly. Weak BVCs are resource-constrained because they do not generate enough revenue to support critical activities, such as enforcement patrols. Furthermore, an organizational network analysis conducted in 2015 [24] showed that linkages between BVCs and other sectors such as forestry, parks and wildlife, commercial fisheries associations and decentralized local government and agriculture were generally weak, thereby limiting the ability of BVCs to leverage cross-sectoral support to the management of sanctuaries.

Conflicts between BVCs and commercial fishers were, in part, due to failing to involve commercial fishers in the development of fisheries/sanctuary bylaws, the demarcation of fish sanctuaries, and the establishment of sanctuaries in areas that were perceived by commercial fishers to be outside the jurisdiction of BVCs. High fish productivity in sanctuaries also attracted illegal fishing from artisanal fishers—creating conflicts between BVCs and artisanal fishermen. These conflicts were compounded by unclear by-laws and management regulations [1] and lack of a specific legal framework for managing fish sanctuaries. According to Day et al. [1], freshwater protected laws should protect sanctuary management from unreasonable local pressures, by including clear objectives and a detailed process for achieving them.

5. Conclusions

The monitoring results of community-managed fish sanctuaries in Malawi's four lakes demonstrated that sanctuaries are suitable EAFM tools, able to restore fisheries' biodiversity and habitats, enhance fisheries' productivity through spill-over effects, and foster environmental stewardship. Hence, community-managed sanctuaries could be scaled up to the rest of Lake Malawi as part of a broader package of BVC strengthening and implementation of EAFM. Based on the Malawi experience, sanctuaries can also be applied to other freshwater lakes in Africa.

BVCs that operate within the context of ecosystem-based management and follow common property resource management principles have a higher likelihood of succeeding in managing community-based fish sanctuaries. As outlined in Ostrom's common property resource design principles, it is critical to have both legitimate institutional arrangements that allow for the establishment of sanctuaries and conflict resolution mechanisms in place. Conflicts between sanctuary managers and other resource users can be avoided if there is a clear and specific legal framework that spells out sanctuary management objectives and a process for achieving them. Hence, one way to reduce conflict between BVCs and artisanal and commercial fishers is reviewing the existing enabling legal frameworks and addressing identified gaps.

This study showed that protecting rocky habitats and other critical habitats that naturally support a large diversity of fish species led to better performance than protecting sandy habitats, which have lower fishery biodiversity. The finding that not all lake habitats provide equal conservation and productivity benefits underscores the importance of site selection. Hence, sanctuaries should be established in habitats that have high biodiversity potential and possess characteristics that provide a wide range of ecosystem functions to fisheries. This maximizes the likelihood that the sanctuaries result in positive benefits to fishery biodiversity conservation and productivity. The Malawi experience suggests that site selection based on habitat and other characteristics could be added as a ninth design principle to Elinor Ostrom's framework for collective action in common property resource management.

Finally, the study highlights that it is critical to integrate sanctuary management into the broader socio-ecological context and link the BVCs to defragmented decentralized structures. This includes recognizing the interconnectedness between fisheries and upland ecosystems, such as forests and agricultural lands. Addressing the different ecosystems holistically and creating synergies between management efforts (e.g., by connecting the sanctuaries to bans on shoreline cultivation) maximizes the potential for sustainability, biodiversity, and socio-economic gains.

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