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Joint Biodiversity Management Committees: A Mechanism to Manage and Conserve Eco-Regions

Laladhas Krishna Panicker [1, 2, *], Marcus J. Fila [3], Achuthsankar S Nair [1], Oommen V. Oommen [1, 2]

1. Dept. of Computational Biology & Bioinformatics, University of Kerala, Kariyavattom, Thiruvananthapuram, Kerala – 695581, India; E-Mails: laladhas@gmail.com; achuthsankar@keralauniversity.ac.in; oommenvo@gmail.com
2. CSEIBA: Center for Sustainable Environment-India Biodiversity Action, Thiruvananthapuram, Kerala, India
3. Dept. of Economics and Business, Hope College, Holland, Michigan, 49423, USA; E-Mail: fila@hope.edu

* **Correspondence:** Laladhas Krishna Panicker; E-Mail: laladhas@gmail.com

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Abstract

Sasthamkotta Lake eco-region is a freshwater Ramsar site in Kerala, India. Eco-regions are ecologically and geographically defined larger land or water mass areas with a characteristic assemblage of the ecosystem and significant biodiversity. A decentralized and locally self-sustaining mechanism has been achieved in managing this eco-region by a participatory model through a joint Biodiversity Management Committee (jBMC) constitution. BMCs are custodians of the environment, and biodiversity, confined to a village/Panchayat, as per Convention on Biological Diversity (CBD) guidelines and the Indian Biodiversity Act. This jBMC constitutes a network of statutory biodiversity experts from the BMCs of three Local Self Governments (LSGs) or Panchayath administrations, where the Sasthamkotta Lake is located. It has been formed to develop strategies to manage and conserve the freshwater lake and its biodiversity. The management action plan proposed by the jBMC for the Sasthamkotta

Ramsar site includes systematic and continuous assessment of the current biodiversity status, identifying and mitigating threats, appropriate use of its resources for eco-restoration and better administrative programs for biodiversity enhancement. Our case study shows that the conservation model of a Ramsar site Eco-region is successful and could be replicated in other damaged natural ecosystems which need attention, for a sustainable future.

Keywords
Biodiversity act; biodiversity management committees; joint biodiversity management committee; jBMC; Ramsar sites conservation; eco-regions; decentralized planning; eco-restoration; natural ecosystems

1. Introduction

Eco-regions are ecologically and geographically defined larger land or water mass areas with a characteristic assemblage of the ecosystem and significant biodiversity [1]. Local Self Governments (LSGs) are statutory decentralized Government institutions for local administration characterized by pluralistic biodiversity and ecologically sensitive regions. The conservation and management of Sasthamkotta Lake, a Ramsar site in Kerala State has been successfully carried out as per United Nations Convention on Biodiversity (CBD), directed by the Indian Biological Diversity Act 2002 by a participatory and Biodiversity Management Committee (BMC) governed protocol [2].

CBD is an international legally-binding agreement to conserve biodiversity at all levels, which includes ecosystems, species and genetic diversity. The conservation of biodiversity, sustainable use and the fair and equitable sharing of the benefits of using genetic resources, are worthy goals for life on Earth [3]. The prime objective is to encourage actions that lead to a sustainable future. Ecosystems and the genetic diversity available include animals, plants, fungi, and microorganisms. Therefore, an ecosystem approach with a strong framework for an integrated strategy is necessary. Moreover, local-level bio-resources management is possible by measuring the ecosystem service's value and biodiversity.

CBD insists that each party develops a National Biodiversity Strategy and Action Plan (NBSAP) to promulgate the objectives of the Convention at national, regional and local levels and in all sectors in each country (Article 6) [4]. The national biodiversity strategy reflects India’s vision for biodiversity and the broad policy and institutional measures that the country proposes to fulfill the Convention's objectives [5]. The Ramsar Convention on Wetlands and the Convention of Parties' decisions relate to inland waters that visualize the framework for conserving wetlands ecosystems along with their rich diversity of life, performing great service to mankind and other forms of life [6].

1.1 Policy Frameworks for Conserving Wetlands Biodiversity

After ratification of the Ramsar Convention in 1982, the Government of India established the Ministry of Environment, Forest and Climate Change (MoEF&CC, the then MoEF) in 1985 which plays a key role in articulating wetlands policy elements within the national environmental policy. A national wetlands program to support state governments in implementing integrated wetland

management plans was established in 1986- the program is currently known as the National Plan for Conservation of Aquatic Ecosystems (NPCA) [7]. The National Biodiversity Action Plan (2014 Addendum to 2008 Plan) proposed the recommendation of the integration of wetlands in the river basin with 'in-situ' biodiversity conservation strategies [5]. Major gaps identified in the conservation of natural ecosystems are the lack of data regarding the living beings in the area. Documenting the status of biodiversity in the wetland or natural ecosystem and determining the biological status, including endemicity and threatened status, is more established nowadays, thanks to the onset of inventory of global databases as well as the combination of a selection of global data reports and links [8].

The value of wetlands as an important water source and sink for sediments and nutrients is now better understood. For example, the rampant loss of wetlands that the country has witnessed in the last four decades is seldom seen as a water security threat. From a regulatory standpoint, Wetlands (Conservation and Management) Rules, 2017 [9] was notified under Environment (Protection) Act as the national regulatory framework for wetlands. As per the provisions of these rules, State Wetlands Authorities have been constituted as the primary policy and regulatory bodies within the rule. However, despite greater understanding, value, and regulatory advancement, Ramsar sites are not being managed effectively, sufficiently and scientifically, particularly at the local eco-region level.

India became a signatory to the Convention on Wetlands of International Importance (Ramsar Convention) in October 1981, with two sites. As a contracting party to the Ramsar Convention, India is committed to promoting the conservation and wise use of wetlands nationwide. India has 42 sites designated as Wetlands of International Importance (Ramsar Sites) [10]. These cover a surface area of 1,081,438 hectares and form an impressive stretch of wetlands of both fresh and brackish water. The state of Kerala presently has three Wetlands of International Importance: Vembanad-Kol wetlands, Sasthamkotta Lake and Ashtamudi. Of these, Sasthamkotta is the largest freshwater lake in Kerala, and supplies drinking water to more than half a million people (6 lakhs) of Kollam Corporation.

1.2 Protecting Wetlands in India: Regulatory Frameworks

Although the first National Water Policy was framed in 1987, the conservation of water bodies was only addressed in 2002, at the time of revision of the first National Water Policy [11]. Because most of the lakes are in urban areas, they are more prone to degradation and encroachment than those in rural areas. Subsequently, the ministry developed a separate program of the National Lake Conservation Plan in 2001. In February 2013, the National Lake Conservation Plan (NLCP) and the National Wetland Conservation Plan (NWCP) [7] were merged into a single program called the National Plan for Conservation of Aquatic Ecosystems [7]. There are also many Acts/Bills for restoring lakes and other water bodies in India, in addition to the policy statement mentioned above. These include the Ramsar Convention on Wetlands of 1971; the Water (Prevention and Control of Pollution) Act of 1974; The Environment (Protection) Act of 1986; and The Biological Diversity Act of 2002. Kerala is one such state, that also passed the Kerala Conservation of Paddy Land and Wetland Act in 2008.

The freshwater ecosystem of Sasthamkotta is under threat, with almost one in three freshwater species threatened with extinction. Furthermore, all taxonomic groups are at greater risk of

extinction than the terrestrial system [12]. Reasons include habitat degradation, a major threat due to myriad adverse conditions, including pollution or flow modification, over-exploitation, encroachment, invasive species [13] and river sand mining [14].

Conservation projects fail to protect freshwater species or habitats [15-17] partly because protecting freshwater environments often requires large-scale, multi-sectored and multi-dimensional efforts [18], which can be difficult to undertake, co-ordinate and manage. Consequences of this failure carry significant implications, for example, essential human dietary protein demand is met through fish consumption from the aquatic ecosystem. As per UN FAO estimates, fish consumption (including freshwater) provides more than 3.3 billion with at least 20% of their animal protein intake, and the fisheries and aquaculture sectors provide huge employment for about 59.5 million people, the majority of unsustainable practices [19].

In summary, a wetland is more stable and productive with the conservation of its pluralistic biodiversity along with a sustained ecosystem. Different authors from diverse regions have reported successful and well sustained ecosystems. A decentralized governance strategy adopted successfully at the ecosystem level for Sustainable Development has been reported by different authors [20-23]. Conservation of wetland ecosystems through the Sustainability of Native Fish diversity and rural livelihood has been well documented [24, 25]. Biodiversity Conservation Challenges for the future have also been reported by different authors [26, 27].

The management action plan proposed by jBMC for the Sasthamkotta Ramsar site comprises a systematic and continuous assessment of the current biodiversity status, identification and mitigation of threats, wise use of its resources and eco-restoration and biodiversity enhancement programs. This paper demonstrates a successful conservation model of a Ramsar site eco-region that could be replicated in other damaged natural ecosystems which need attention for a sustainable future.

2. Methodology

2.1 Joint Biodiversity Management Committee for Sasthamkotta Lake

BMCs have been constituted [28, 29] at LSGs of Kerala to manage biodiversity. However, the territory of Sasthamkotta Lake extends beyond one LSG revenue land area and has three LSGs. Section 12 (xxv and xxvi) of Kerala State Biodiversity Rule 2007 empowers Kerala State Biodiversity Board (KSBB) to coordinate the activities of the BMCs and give direction for effective implementation of the Act to facilitate their meaningful participation in all measures relating to conservation, sustainable use and equitable benefit sharing. A jBMC consisting of BMC members of the three Grama Panchayats of Sasthamkotta, Mynagapally and West Kallada (Figure 1) was constituted with the Sasthamcotta block Panchayat president as its Chairman. There are 941 BMCs (Panchayats), 152 block Panchayats and 14 District Panchayats in Kerala. The chairpersons of three BMCs were added as joint conveners and the members of the BMCs were included as their executive members in the jBMC. A comprehensive management action plan was subsequently proposed to protect the watershed connectivity and pollution mitigation measures with conservation strategies for the floral/faunal biodiversity of the lake.

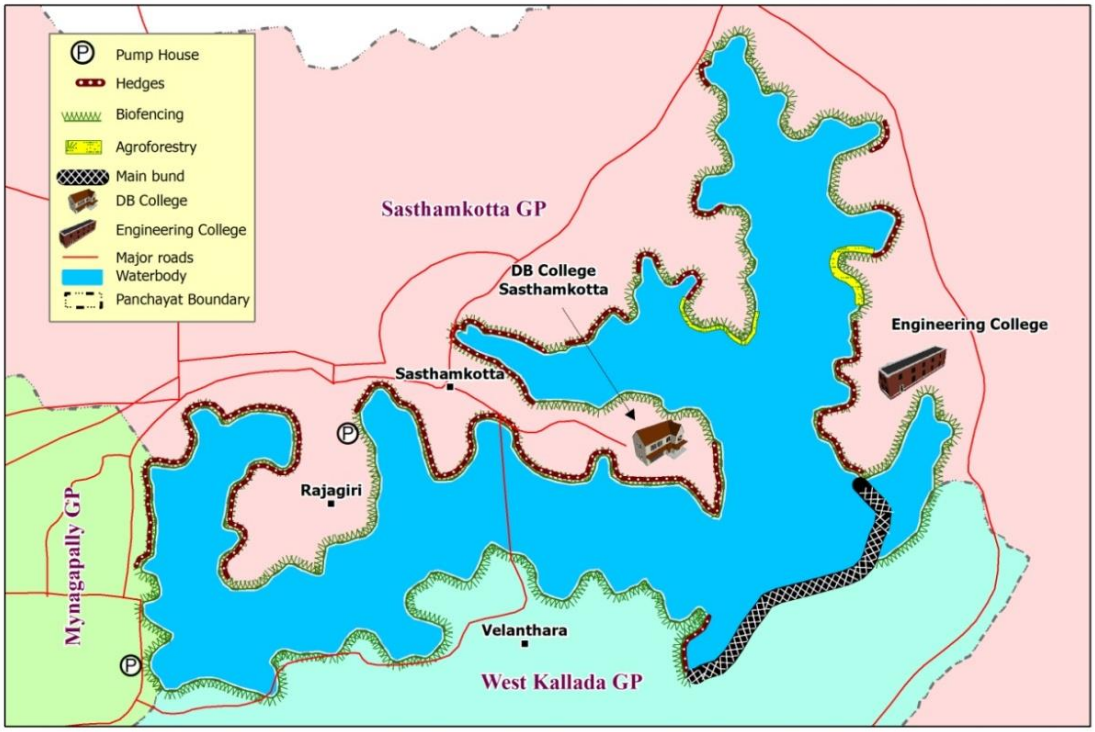

Figure 1 Map showing the geographical area within three Panchayats. **(Kerala State Biodiversity Board).**

As part of the conservation program, the KSBB created a Biodiversity register with detailed information on the flora and fauna of the Sasthamkotta wetland system with the participation of people (local stakeholders), and it was released in 2016 [30].

3. Sasthamkotta Lake

The lake has been a designated wetland of conservation importance under the Ramsar Convention since November 2002 and was declared a Ramsar site on 18.08.2012. The lake lies ~30 km (by road) away from Kollam town between North Latitude 9°1'35'' to 9°3'17'' and East Longitude 76°36'42'' to 76°38'41'' (coordinates 9.0356°N, 76.6369°E), which spread out in three revenue villages (Sasthamkotta, Mynagapally, West Kallada) of Kunnathur taluk, Kollam District (Figure 2 and Figure 3). The Lake can hold 22390 million liters of water. It does not get frozen in winter and fresh water is available throughout the year. The lake is replenished by water from direct rainfall, runoff from surrounding upper catchments, and subsurface runoff/underground recharge and recharge from the flood plain lying to the southern area of the Lake and from the Kallada River. There are no visible tributaries feeding the lake. Hills surround it except in the south, where a bund has been constructed separating the lake from the neighboring paddy fields.

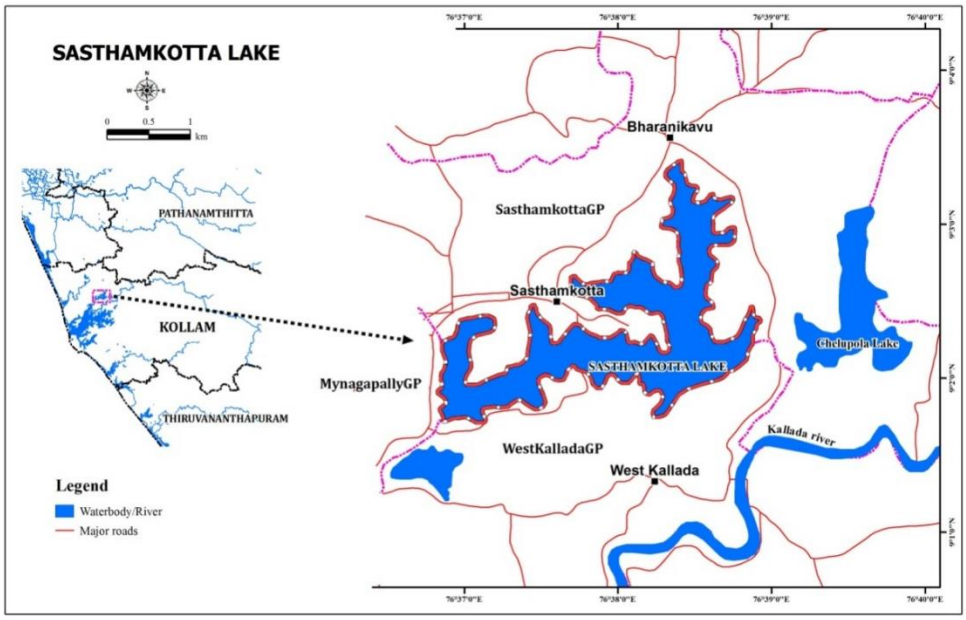

Figure 2 Map showing location of Sasthamkotta lake. **(Kerala State Biodiversity Board).**

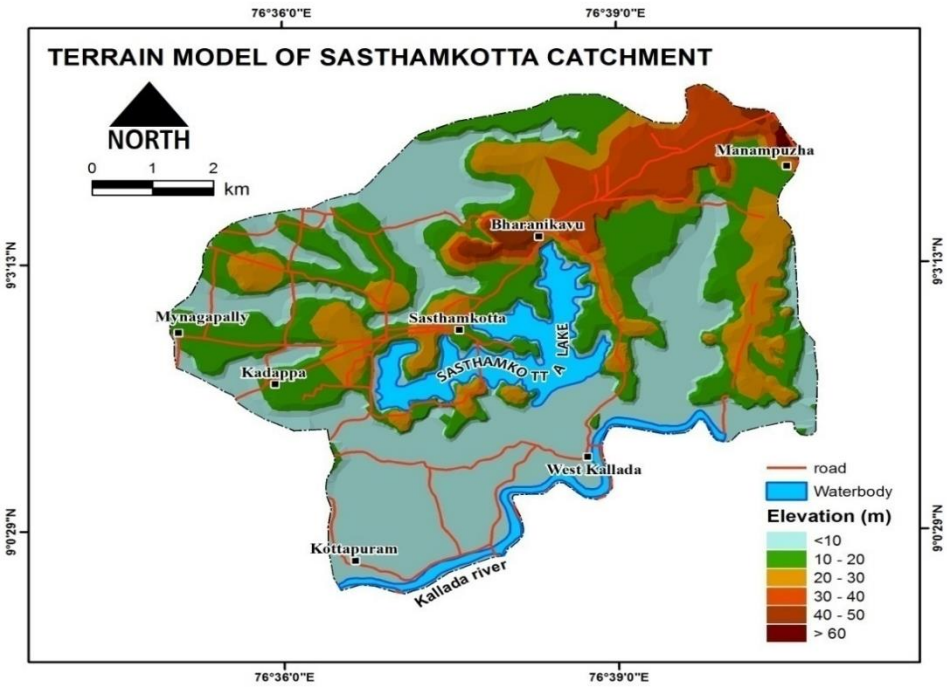

Figure 3 Digital terrain model of Sasthamkotta Lake Catchment. **(Kerala State Biodiversity Board).**

3.1 Physical and Biological Assessment

3.1.1 Physical Characteristics

The lake has an inverted shape of the English letter 'F' (Figure 4) with a number of both small and large creeks. The area receives an annual average rainfall of 2145.9 mm with a mean annual temperature between 26.7°C and 29.16°C. The groundwater table is at a depth of 3.89 m [31, 32].

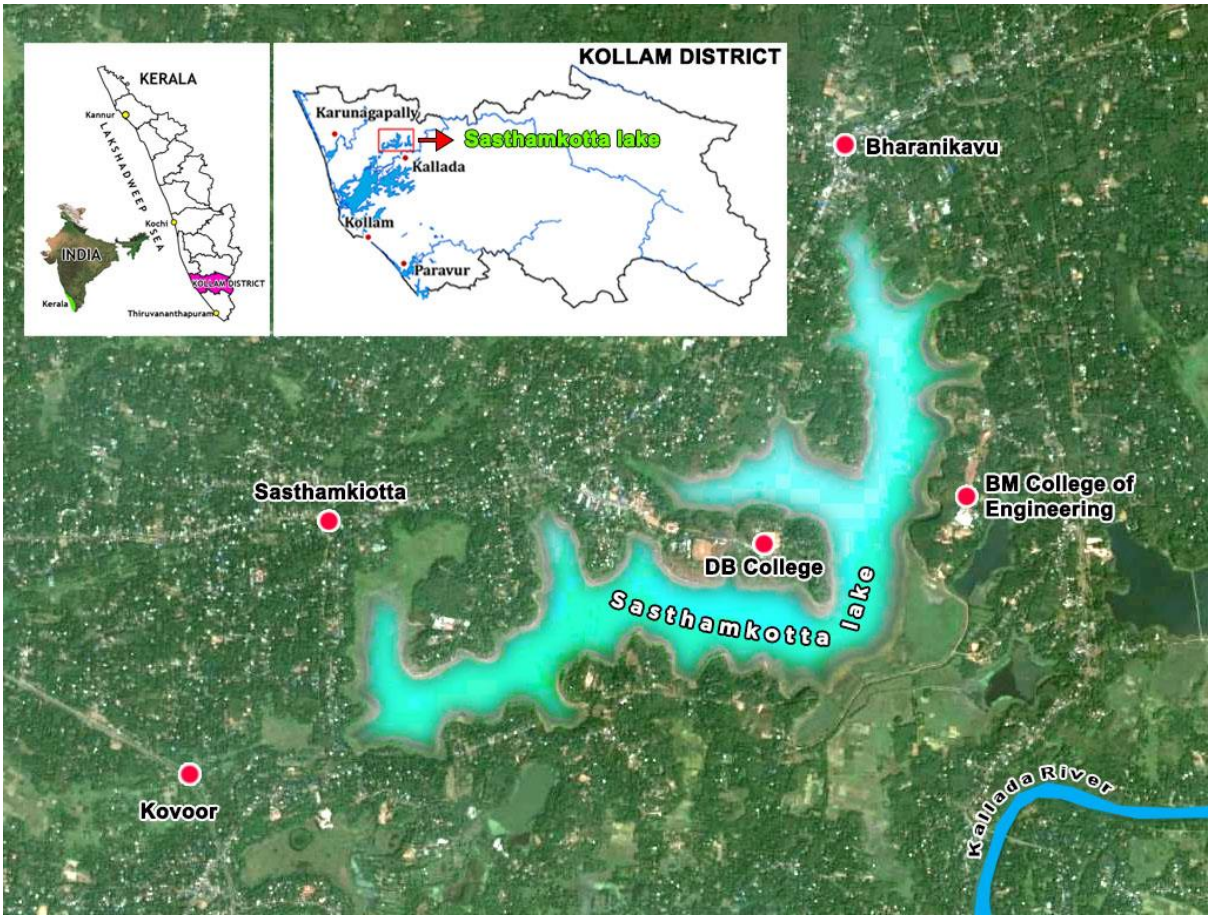

Figure 4 Aerial view of Sasthamkotta Lake. **(Kerala State Biodiversity Board).**

3.2 Ecological Characteristics

The physicochemical characteristics of the lake influence the abundance and diversity in biotic communities. The water in the lake is special in that it does not contain common salt or other minerals and metals. Few water plants grow in the lake. A larva called "Chavaborus" live in the lake. These are larvae of insects from the order Chaoboridae, commonly known as glass worms or phantom midges, a family of fairly common midges with a cosmopolitan distribution. They consume the viruses and bacteria in the water, thus contributing substantially to its high degree of purity [31, 32]. Phytoplankton is scarce and primary productivity is low. The Lake has an agricultural watershed with a coconut-based homestead agroforestry system intermixed with trees such as *Mangifera indica, Artocarpus integrifolia* etc. The main crops grown are cashew, coconut, tapioca, areca nut, and mango [30, 32].

3.3 Phytoplankton

As per studies, 36 species from 30 genera belonging to four families were identified from Sasthamkotta Lake. Bacillariophyceae (16 genera); Chlorophyceae (10 genera); Cyanophyceae (3 genera) and Dinoflagellata (1 genera). The slightly acidic nature of water, scarcity of nutrients and the dominance of zooplankton may be the reason for the low primary productivity and phytoplankton concentration in the lake [30].

3.4 Zooplankton

Six groups of Zooplanktons are reported from Sasthamkotta Lake viz., Crustacea, Ostracods, Rotifera, Nematodes, Halobates and Cladocera [30].

3.5 Benthos

The benthic fauna of the Lake is categorized under three orders with 13 families. Among them order Trichoptera was the major group with seven families. In the order Diptera the family Chaoboridae is the dominant one. Chavoborus is the third dominant group among the benthic population [30].

3.6 Flora

The lake's catchment area contains 60 species of plants including endangered and near threatened categories. Some of them are *Borassus flabellifer* (Bojer ex Jum. & H.Perrier) and *Opeaparviflora* (Bedd.) etc [30].

3.7 Fauna

The faunal diversity in the lake and its catchments includes unique, rare, endangered, abundant or bio-geographically important species. The lake has fish species such as *Dayella malabarica* (Day) and Herring's Sardines of the family Clupeidae. The wetland supports 27 fish species including some indigenous species like *Puntius ntictopunctatus* (Day), *Puntius saranasubnasutus* (Ham.), *Horabagrus brachysoma* (Gunther), *Etroplus suratensis* (Bloch), *Aplocheilus lineatus* (Val.), *Parambassi Thomas* (Day) and *Macrognathus guentheri* [30, 33]. They swim in schools generally near shores. The most common fish in the lake is "*Callichrous bimaculatus* and *wallago attu*". The fish is so called because most are provided with whiskers-like barbells arranged around the mouth. These are considered sacred and therefore not caught [31]. The bird population of Sasthamkotta Lake includes 60 species. The adjoining marshy and fallow lands provide habitat for resident and migratory birds such as *Anasquerquedula* and *Anasacuta*. The butterfly diversity of the Lake includes~23 species [30]. Nearly 71% of the migratory water birds of the Central Asian Flyway (CAF) use India as a breakpoint. Therefore, sustaining the health of Indian wetlands is crucial for conserving the global migratory water bird populations within the Flyway [9].

3.8 Environmental Issues Identified from Sasthamkotta Lake

Sasthamkotta Lake was under severe environmental threat and experienced degradation because of various anthropogenic activities. The water level decreased and the load of pollution progressively increased. The increase in population reduced land availability and resulted in the vanishing of critical habitats. A huge amount of domestic solid and liquid wastes plundered into the lake’s periphery, worsened the Lake’s environmental health. Lack of appropriate awareness and inadequate technical and financial support were the main challenges behind conservation.

3.9 Watershed Degradation and Biodiversity Loss in Sasthamkotta Lake

The main problems faced by the lake were:

i) Pollution of freshwater due to domestic and sanitary disposal
ii) Filling up of shallow land mass for cultivation
iii) Large-scale destruction of natural vegetation resulting in degradation of catchment and siltation
iv) Sedimentation leads to a reduction in the depth and volume of the lake
v) Loss of biodiversity
vi) Soil erosion
vii) Pollution and weed infestation
viii) Unsustainable fishing

Siltation and high sediment load due to soil erosion were the major causes of lake degradation. The absence of soil and water conservation measures augmented the pace of soil erosion. During monsoon, the runoff rate becomes high and soil erosion peaks. Thus, the fertile topsoil is washed off every year causing leaching and washing off nutrients leading to siltation and pollution in the lake. Tree felling causes soil loss affecting rainfall patterns, and loss of various aquatic species due to water-level fluctuation. Siltation diminished the quantum of water flow and destroyed the breeding grounds of fishes. Watershed development through planting suitable species to enhance the green cover is the best developmental approach to cope up with these anomalies.

4. Results

4.1 Remedial Strategies

jBMC [34] has implemented the remedial and conservation strategies for the lake as per the integrated management action plan proposed by experts from groundwater resources, the Biodiversity board, Departments of Environment, Fisheries, Agriculture and NGOs [35].

4.2 Regulating the Over-Exploitation of Natural Resources; Drinking Water

The jBMC has directed the Kerala Water Authority (KWA) to limit the exploitation of water from the conserved lake [36]. During the summer, the demand for water harvest escalates and the huge lake catchment area lake gets dried, posing a severe threat to the ecosystem. KWA extracts 70 million liters of water daily to supply the water demand of Kollam city. As a result of over-exploitation, the water table in the surrounding area went down, posing difficulty to the drinking requirements of nearby residents. Alternate drinking water schemes were proposed to overcome the issue.

An alternate drinking water project was initiated in the Kallada River at Kadapuzha, and a 4.5 km lengthy pipeline connecting the purification station and the distribution outlets was initiated. The project is solely for the conservation of Sasthamkotta Lake and to stop the over-harvesting of water. These alternate drinking water schemes were designed by making a check dam in the Kallada River. Water is pumped out for purification and stored in an elevated spot before distribution for drinking purposes, to spare lake water.

4.3 Abatement of Pollution

To improve sanitation around the lake's catchment, toilets with septic tanks were constructed for all households under the restoration programs by the local self-governments. As part of the

program, a sewage treatment plant was installed at the taluk hospital promising to reduce the pollution load. Controlling measures were adopted to regulate the discharge of stormwater runoff to the lake. Collection waste bins were placed at specific locations to regularly remove waste. Households were motivated for onsite management of a biodegradable portion of solid wastes by adopting bin/ring composting, pit composting, vermin composting etc. Measures were taken to reduce agricultural runoff containing pesticides and pollutants entering the lake. Organic farming is promoted with the help of various schemes involving kudumbasree (Women's self-help group) units working in these Panchayats.

4.4 Modern Sanitation Facility for Coliform Mitigation

A modern sanitation facility for the rural public (at the cost of Rs. 16, 53,440) was initiated near the premises of Sasthamkotta Lake in order to prevent the leaching of coliform bacteria contained in fecal wastes. Open defecation was completely prevented by allotting 239 modern sanitation facilities with a septic tank for proper waste management to the poor local public.

4.5 Catchment Management Programs

Comprehensive catchment management of the Lake by afforestation was necessary for soil and water conservation. The planting of trees was carried out in the project area with the multi-objectives of soil conservation, water recharge and eco-restoration. Afforestation in the catchment with indigenous species helps to prevent sedimentation of the lake. Terracing on slopes to reduce erosion and reforestation to check seepage were also targeted.

The drainage area/catchment of the Lake can be divided into 23 Mini watersheds/Units. Activities under this project focused on increasing the area under vegetation and grasses through afforestation, increasing the availability of green and dry fodder, both in quality and quantity and habitat improvement through soil and moisture conservation works.

Green Belt: A green belt was developed to prevent encroachments and anthropogenic activities for 5 meters from the water periphery using bamboo and other suitable species. More grass species, vetiver (*Chrysopogon zizanioides*), bamboo, reeds etc were planted for effective soil and water conservation. This improved the opportunities in the watershed to produce quality cattle fodder, increasing milk production. Bamboo and Pandanus were cultivated in barren and sloppy areas and in the embankments. Silt/pollution-laden runoff traversed through certain areas before mixing with water. These patches were developed into filter strips by establishing cover crops including vetiver and other plants. These green belts would help regulate the lake bank heating up, leading to excessive evaporation.

Bio-fencing: Live fencing of individual land holdings by species like Gliricidia, Hibiscus, and Pandanus, was targeted. Saplings of trees having a large canopy were planted under the scheme. Evergreen shade trees like *Azadiracta indica, Calophyllum inophyllum, Millettia pinnata* and *Saracaasoca* were planted for the best protection from the summer sun.

Soil erosion was prevented by greening the surroundings using bio-fencing, vetiver bunds, fodder grass and earthen bunds. Riparian vegetation, and trees were also planted for regulating soil erosion.

Agroforestry: Most of the catchment area is private and has an agricultural watershed with coconut-based farming intermixed with trees. To promote these, crops such as coconut, tapioca and

areca nuts were supplemented to grow here. Hence homestead-based agro-forestry has been promoted by distributing saplings of common timber species and multipurpose tree species such as mango, jack, tamarind, gliricidia etc.

4.6 Removal of Invasive Alien Species from Ramsar Site

Joint BMC initiated biodiversity restoration programs in the Sasthamkotta Lake region for conserving endemic flora. Data on invasive alien species cultivated in the adjoining area of the Lake was collected and recorded. Huge numbers of planted acacia (*Acacia auriculiformis*) eucalyptus (*Eucalyptus globulus*) and mangium (*Acacia acacia*), the invasive trees have grown thickly in the catchment area of the lake that posed a severe threat to the endemic diversity, were removed from adjoining revenue land. A people's participatory program was organized to give awareness for conserving endemic diversity, helping prevent the threats of alien diversities to the ecosystem.

4.7 Afforestation Program in the Adjoining Ecosystem

Joint BMC proposed a comprehensive catchment management program for the lake to conserve soil erosion by enriching endemic floral and riparian diversities through intensive afforestation programs. A bio-fence of 2.5 km was also developed with the help of MNREGS (Mahatma et al. Scheme) volunteers to protect the shoreline from encroachment. Host plants of butterflies such as Crotalaria sp., Hibiscus ssp., Cassia ssp., Albizia sp., Aegle marmelos, Citrus ssp. etc. were planted in the open areas of the catchment. An area of 1.07 hectares vested under the forest department was used for planting a year aged 2629 saplings of traditional trees and agro-biodiversity seedlings. 4500 saplings were planted on June 5th 2014, world environment day [34].

4.8 Conservation of Avian Fauna

The joint BMC is actively engaged in the conservation of avian fauna through volunteers by preventing hunting, planting saplings of suitable trees and protecting the eggs and chicks of the migratory birds visiting that area. Improvement of this habitat was done by the construction of artificial nesting grounds, earthen mounds and the planting of native trees.

4.9 Enhancing Endemic Fish Diversity

For the revival of the fishery resource of Sasthamkotta, threatened taxa were identified, representative species were propagated in the nursery and fingerlings were reintroduced. Volunteers were posted to prevent fishing by poisoning the lake water and banning nets etc. Fish farming was also promoted as an alternate livelihood option for fishermen's communities to control the exploitation of fishery resources.

4.10 Awareness Campaign

To create awareness among the public, sign boards informing Do's and Don'ts are displayed in the surrounding area. Pamphlets were prepared and circulated in schools, colleges and among the local populace. Awareness campaigns were conducted for local inhabitants and city dwellers on the need for conservation and wise use of the wetland, and seminars on solid waste management at

household and community levels. Social media was also used spread the conservation message of the internationally important Ramsar site for the benefit of future generations. Ten display hoardings were erected at the entry points for public awareness to conserve the Lake.

4.11 Ecosystem and Biodiversity Conservation of Sasthamkotta Lake

jBMC initiated its conservation programs on 18 March 2015 with joint support from KSBB, LSG and MNREGS. Altogether six meetings were conducted by the jBMC and formulated the following conservation programs. During the period a total of 16080 tree saplings were planted in the surrounding catchment areas. 2514 tree guards were fixed for the safety of the saplings in the inhabited area. A three-kilometer stretch of lake boundary was bio-fenced with *Gliricidia sepium,* a common name quick stick (Vernacular-Cheemakonna) from the Fabaceae/Leguminosae family as a participatory conservation program, a total of 23 cluster meetings have been organized for awareness with the participation of 400 stakeholders. Nine thousand saplings were planted during the 2016-17 period by the funding of the Department of Environment and Climate Change, a total of 3452 tree guards were also fixed for its protection. A total of 25, 000 saplings were successfully planted in the adjoining area of Sasthamkotta Lake between the financial years 2015 to 2017 and the conservation and continuous monitoring of the tree saplings was carried out by MNREGS volunteers.

4.12 Long-Term Conservation Strategy

The project was designed and implemented with local people's active support and involvement,, ensuring employment opportunities. The labor force available with the Grama Panchayat under the MNREGS was a powerful manpower resource.

For the conservation of planted saplings and the monitoring of adjoining biodiversity and ecosystem, a total of 2857 manpower days were spent by MNREGS. For the financial year 2016-17, 2148 manpower days were utilized. A total of Rs. 1787220/has been spent by the jBMC for the overall conservation programs of Sasthamkotta Lake for its own projects.

As per the mission of the Ramsar Convention, jBMC of Sasthamkotta Lake initiated the conservation and wise use of Sasthamkotta wetlands through local action, as a contribution towards achieving sustainable development of the fourth strategic plan [37] 2016-2024. ***"Wetlands are conserved, wisely used, restored and their benefits are recognized and valued by all"****.*

4.13 Conservation Strategies and Management Action Program for Sasthamkotta Lake

There is an urgent need to adopt long-term conservation measures based on definite plans with a sound ecological approach. Considering the problems facing the wetland, some mitigation measures are suggested (Table 1).

Table 1 Environmental Threats and mitigation measures of Sasthamkotta Lake.

No	Threats	Reason	Remedy	Long term
1	Reduction in the lake volume	Reclamation activity and siltation	Stop quarrying in the catchment area	Afforestation in the catchment

2	Reduction in the lake size	Encroachment	Stop further encroachment	Resurvey of the lake
3	Siltation	Indiscriminate land activities	reduce erosion	Terracing on slopes and reforestation
4	Drainage	no well-planned drainage system in the watershed	Avoid public drainage	recycling of domestic grey water and biodegradable solid wastes
5	Reduction of the breeding grounds of fishes,	habitat destruction	prevent sedimentation of the lake	Conservation of indigenous species
6	Coliform bacteria	Open defecation	Sanitation facility	Modern/scientific sanitation facilities
7	Direct Pollution	Bathing & washing	Regulated usage	Alternate facility for bathing, washing clothes and cattle.
8	Pollution	waste water from filter house	Stoppage of waste water discharged	separate earth tanks are to be built for discharging
9	Eutrophication	Aquatic weeds	Removal	Controlled growth of weeds
10	Alien species	Invasive & planting	Removal	Planting traditional & endemic diversity
11	Water quality	Reduce pollution	Regular monitoring	Pollution control
12	Conservation threats	Biodiversity loss	Conservation of flora & fauna	Ecosystem conservation
13	Tourism	Over crowded	Regulate crowd	Sustainable tourism
14	Local people non supportive	Lack of awareness	Mass awareness	Among students, NGOs, stakeholders
15	Weak lake management	empower local management	Local Self Government level	BMC and jBMC management
16	Lack of monitoring	at all levels of lake	Local level continuous monitoring	Daily management by jBMC
17	Resource depletion	Over exploitation	Sustainable utilization	Sustainable resource management by jBMC

5. Discussion

5.1 Decentralized Ecosystem Conservation

India was one of the first countries to have proactive legislation. It enacted a comprehensive Biological Diversity Act in 2002 and The Biodiversity Rules 2004 to implement the provisions of the Convention on Biological Diversity [2]. The Act covers the essential environmental and biodiversity concerns, as follows:

- ❖ To regulate access to the country's biological resources to secure an equitable share in benefits arising from the use of biological resources and associated traditional knowledge.
- ❖ To conserve and sustainably use our precious biological resources.
- ❖ To conserve and protect traditional knowledge of local communities relating to biodiversity.
- ❖ Conservation and development of areas of importance from the perspective of biological diversity and ecosystem including wetlands by declaring them as Biodiversity Heritage Sites.
- ❖ Government involvement in implementing the Biological Diversity Act through the constitution of State Biodiversity Boards (SBB) and Biodiversity Management Committees (BMC) locally.

The Act extends to the whole of India and reaffirms the state's sovereign rights over its biological resources.The Biological Diversity Act is implemented in India through a three-tier decentralized system comprising the National Biodiversity Authority (NBA) functioning at the National level, the State Biodiversity Boards (SBBs) at the Federal level and the Biodiversity Management Committees (BMCs) constituted at the local level (LSG-Level) i.e. the Grama Panchayats, Municipalities and Corporations which act as the three-tier system. The Kerala State Government established the Kerala State Biodiversity Board (KSBB) in 2005 and formulated Kerala State Biological Diversity Rules in 2008. KSBB initiated the constitution of BMCs in all its LSGs. Kerala was the pioneering State implementing the institutional structure for the conservation of biodiversity at the grass root level in India.

5.2 Biodiversity Governance at the Local Level by BMC

BMCs are statutory bodies at the local level consisting of eight members constituted by Section 41 of the Act 2002 and Section 22 of the Rules, 2004 [2]. BMCs are constituted to document biological diversity, promote conservation, sustainable use of bio-resources, including preservation of habitats, conservation of landraces, folk varieties and cultivars, domesticated stocks and breeds of animals and microorganisms and documentation of knowledge relating to biological diversity. Kerala is the first State in the Country to have constituted BMC's in all the LSG's as early as 2012 itself. Thus a total of 1107 BMCs are now functioning in the State covering its geographical territory.

The structure and design of the constitution of BMC in Kerala are different from that of the other States. In Kerala, the President of LSG is the Chairman of the BMC, who has power in decision-making and implementation of programs about biodiversity conservation and the ecosystem. The BMC consists of a Chairperson, Secretary and six members nominated by the local body. Of the six members, one-third should be women and not less than 18% should belong to the Scheduled Castes/Scheduled Tribes. The BMC members should be selected from amongst the herbalists, agriculturists, bio-resource collectors and traders of Non-timber Forest Produce (NTFP), fisher folk, traditional knowledge holders, community workers, academicians and any other person/representative of the organization, on whom the local body trusts that they can significantly contribute to the mandate of the BMC. All the members should be residents of the local body and be on the voters' list. The tenure of the BMC is five years from the date of its constitution.

The responsibility of the BMC is to document the data regarding biodiversity, ecosystems, etc; prepare the People's Biodiversity Register (PBR) in consultation with the local people. The register contains comprehensive information on available biological resources and associated traditional knowledge within its area of jurisdiction. The statutory authorizations of prepared PBRs are done

by KSBB and maintained by the BMCs. The NBA and the SBB provide guidance and technical support to the BMCs for preparing PBRs.

5.3 BMC; A Capacity Enabled Stewardship

The government of Kerala has designated BMC as an environment Watch Group as per Govt. Order to act upon local environmental issues [38]. Having established functional BMCs in all LSGs by the end of 2012, capacity building across all the BMCs by creating awareness about the Biodiversity Act and Rules was conducted to better administer biodiversity in their jurisdiction. A series of training programs were conducted to strengthen BMCs at the Block Panchayath level throughout the state by the KSBB. BMC empowerment program was held for Panchayath Presidents (BMC chairpersons) and Secretaries through District Panchayaths with the support of field staff and experts of the Board. A guideline for BMC operation including their roles and responsibilities, along with the formats for recording minutes of meetings, submission of annual reports, knowledge of traditional knowledge holders, auditing of accounts, and development of local biodiversity strategies and action plans in regional language was prepared to edify the BMC. As per section 43 (1) of the Biodiversity Act 2002, the Board constituted Local biodiversity funds. As a result of all the awareness mentioned above/strengthening/empowerment programs, BMCs of Kerala have started to play a key role in conserving the biodiversity of their locality and several BMCs have come up with conservation projects and the KSBB has facilitated the starting of Local Biodiversity fund. Joint BMCs have been constituted with the Block Panchayath President as the Chairman with a core committee of BMC members of the adjoining BMCs to facilitate the conservation of areas beyond the boundary of a revenue Panchayath.

5.4 Technical Support Group (TSG) for BMC

KSBB has formulated a Technical Support Group (TSG) at local and district levels with two-tier mechanisms to offer scientific and technical support in all BMC activities. The structure comprises experts from various disciplines and line departments, universities, research institutes, colleges, schools and non-governmental organizations, competent enough to advise the BMC. The TSGs give input at the local level during the PBR preparation and on environmental and biodiversity issues, at the district level. The local level TSG comprises not less than seven members, constituted by the BMC, including the experts in their jurisdiction. The Board constitutes district-level TSGs and comprises 5 experts from various fields of biodiversity. They help the BMCs to monitor and evaluate various processes of PBR documentation. The TSG provides technical inputs and advises the BMCs on identifying flora and fauna, monitors and evaluates PBR exercise and maintains a database of local and external experts on biodiversity. They also help the BMC to include the current conservation practices of communities in the PBR. The TSGs for LSG are also a model successfully implemented in Kerala to strengthen the institutional capacity of the local community/BMC for implementing the Biodiversity Act. Kerala has completed the preparation of PBRs in all BMCs by the year 2020 and it is the first and only State in the country to have achieved this target.

5.5 Monitoring Wetlands Biodiversity and Ecosystem Health

An important criterion linked with the designation of Ramsar Sites is to keep the commitment of updating the ecological characteristics of such sites on the Ramsar Information sheet once every six years. This has been a hectic task and a challenge globally. Normally such a task is handled as a project called the National wetland program by the Ministry of Environment, Forest and climate change as an obligation of agreement. This responsibility is vested with the BMC according to the Biodiversity Act 2002 to successfully update and monitor the biodiversity and ecosystem health of the Ramsar sites. Experts designed locally from educational institutions or research centers do biodiversity assessment and monitoring. An established team of geology, biodiversity and environment experts did a detailed checklist based on taxonomic classification. JBMC constituted this to assess the ecosystem health by studying water quality, the status of biodiversity and environmental parameters. Stewardship of Comprehensive ecosystem monitoring and biodiversity conservation in various wetlands has been reported by Cantonati et al. 2020 [39, 40].

Climate change globally threatens all ecosystems on earth and the species they inhabit, and adversely retrograde the services and resources they provide to humans [41]. Freshwater is a precious resource; almost 7% of global biodiversity in freshwater is tiny in its area and relative volume [13]. The ecosystem's future and biodiversity in the precious environment is uncertain due to climate change, contamination, excess water harvesting, impoundment, and intrusion of invasive alien species [42]. Lakes are impacted by climate warming and airborne pollutants in almost all major ecosystems [43, 44]. De Graaf et al. (2019) [45] estimate that two-thirds of the world's developed watersheds will reach environmental flow limits due to over-exploitation and groundwater pumping by 2050. These irreparable impacts on freshwater ecosystems call for an improved understanding of these threats, how they affect biodiversity, and how we can counter them as in the case of Sasthamkotta wetland.

6. Conclusion

The study emphasizes the protection of Sasthamkotta Lake, the largest freshwater lake in Kerala. Sasthamkotta, the only freshwater Ramsar site in Kerala, is a rich ecosystem that harbors several species of organisms giving livelihood to thousands of people around it. This lake falls within the area's three BMCs or Panchayats (LSG). Since it is beyond the scope of one BMC, in order to protect and conserve the lake, a joint biodiversity management committee was formed under the block Panchayat of the region. BMCs are required to document the biodiversity through a people's biodiversity register. Any deterioration in the biodiversity and ecosystem of the Sashamkotta Lake was compared with the already available data. Then protective measures were developed with the help of the region's expert and technical committee. This helped them *in situ-specific* corrective measures to protect the ecosystem. Kerala State Biodiversity Board was concerned with the protection of the lake. We have enriched the biodiversity by planting site-specific trees and protecting the existing trees surrounding the lake. The present case study shows that the conservation model proposed from the Ramsar site can also be implemented in other ecosystems under threat of damage to sustain the natural ecosystem.

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Author Contributions

KPL, ASN and OVO Conceptualized and supervised the work and MJF contributed to the manuscript formation.

Competing Interests

The authors have declared that no competing interests exist.

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