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An Analysis of The Ecological State Risks and Sustainable Governance Strategies of Jaisamand Lake Wetland and Biodiversity Conservation

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Abstract

The second largest man-made freshwater reservoir in semi-arid Udaipur, Rajasthan, Asia is Jaisamand Lake which supports regional biodiversity, hydrology and local livelihoods. This paper is a synthesis of ten years of secondary data to evaluate ecological integrity, define the key threats, and propose sustainable governance.

River inflows at seasons, ground water extraction and climate variation influence hydro-logy and have impacts on water storage, fish living environment and shoreline ecosystem. Invasive species (Oreochromis mossambica), excess in irrigation and urbanization, degradation of the catchment by mining and deforestation, eutrophication and intermittent pollution are some of the major threats. Such pressures have reduced the numbers of the original fish, water productivity, bird habitat, and also, the quality of water in general.

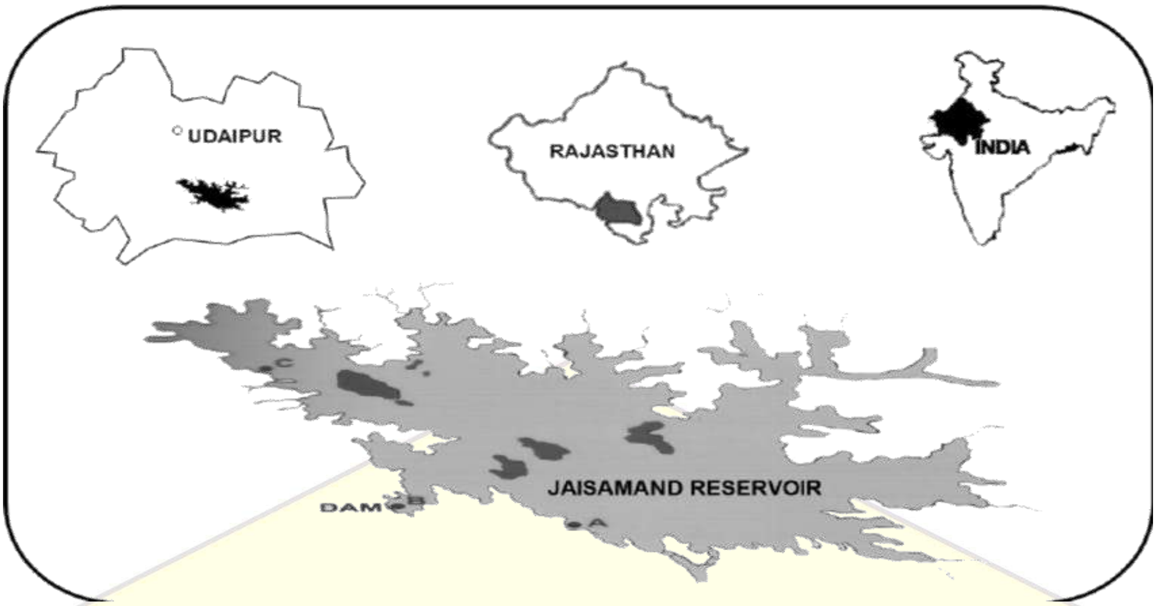
The invasive species control, native fish recovery, controlled water use and environmental flow management, catchment and mining management, nutrient and pollution control, shoreline, zoning, climate adaptation, community-based and participatory management, GIS and remote sensing monitoring and integrated lake basin governance are some of the identified sustainable management measures. It can make it sustainable to the environment, biodiversity and protection of socio-economic prosperity and can guarantee long-term health of this wetland ecosystem when well applied.

Keywords: Jaisamand Lake, Wetland Conservation, Biodiversity, Hydrology, Invasive Species, sustainable Management, Community Participation

Introduction

One of the largest artificial reservoirs of fresh water, the Jaisamand Lake in Udaipur district, Rajasthan, India, is a structure built by Maharana Jai Singh in the 17th century. It covers an area of almost 87sq km (24.25deg-24.58deg N, 73.75deg-74.00deg E) and it is indicative of traditional hydrological knowledge and community-based water management in semi arid area. The climate around is semi-arid having temperatures of up to 45-50degC in the summer and 5-10degC in the winter. The rainfall, especially monsoon rains, July-September, has 60-80% of annual precipitation, the average of which is less than 60 cm. Climate change has changed the patterns of rainfall and temperature variability, which impacted water availability, ecosystem stability, and lake hydrology (Singh et al., 2017).

The lake is supplied by Gomti, Jhamari, Rooparel, and Bagaar rivers, having 414 million cubic meters of storage capacity and the average depth of 30 meters. The rainfall and extraction of water by humans to irrigate, drink, and use it at home are the reason why the water levels of different seasons change (Raja and Singh, 2016). The processes are also relied on by the aquatic and riparian species and other livelihoods that rely on fisheries, agriculture and tourism in the region. Jaisamand Lake is a hot spot in biodiversity. A few of the plants on earth are Acacia leucophloea, A. nilotica, A. catechu, and Tamarindus indica whereas aquatic plants serve the purpose of providing shelter to fish and birds.



Overfishing and destruction of homes and habitats of native and endangered fish, including Mahseer (Tor tor), is a threat. The lake is home to such resident and migrant birds such as Indian Skimmer (Rynchops albicollis), Sarus Crane (Grus antigone), Coot (Fulica atra), Bar headed Goose (Anser indicus), Greylag Goose (Anser anser), and 20,00025,000 coots were found at the lake (Raza and Tehsin, 2003).

Jaisamand Lake or G-WADI program of the UNESCO is provided as a prototype of water management in arid and semi-arid areas.It has seasonal river flows, reliance on monsoons and human pressures that render it suitable in the research on ecosystem-based management, adaptive governance and sustainable livelihoods.

Core Objectives of the Study:

Determine Ecological Health: Determine the health of water of the Jaisamand Lake e.g. fish, birds, and aquatic plants.

Trace Main Threats: Determine the impact of invasive species, contamination, over-fishing, disturbed catchment, variant of land-use and climate on the ecosystem and livelihood.

Sustainable Management Recommended: Recommend invasive species management, controlled water use, catchments and nutrient management, coastal rehabilitation and climate change management.

Promote Community Involvement: Co-management, participatory management, livelihood diversification, and eco-tourism are among the options to be considered to conserve the environment.

Enhance Surveillance and Policy Framework: Put into focus GIS/remote-sensing-based surveillance, gaps of research and incorporated in long-term management of ecological sustainability of lakes basin.

Scope and Methodology

The study of Jaisamand Lake wetland and biodiversity is significant because it is the second largest artificial freshwater reservoir in Asia and a major socio- ecological system in Udaipur, Rajasthan. The lake also offers vital ecosystems services of freshwater, fisheries, recreation, and habitat of endangered fish and migratory birds.

The key threats are overexploitation of groundwater, water pollution, degradation of the catchment area, invasive species and human encroachment. Particular attention is paid to the ecological effects of Oreochromis mossambiqua (Tilapia) on the population of native fish (Dubey, IUCN-WCPA; Sugunan, 1995). Human reliance is emphasized by the fact that approximately 2,500 households are relying on fisheries, irrigation, and eco-tourism (Verma et al., 2015).

The classic and modern management intervention measures, including catchment treatment, control of nutrients, wetland zoning policies, climate adaptation and stewardship of communities are evaluated.The combination of ecological, hydrological and socio-economic views fills the gaps related to insufficient water quality, absence of species-specific biodiversity data and insufficient integration of community perspectives (Prasad et al., 2002; Sharma and Kansal, 2013). The outcomes will enlighten the policymakers and other stakeholders in adaptive management those addresses the ecological and socio-economic well-being.

Methodology

The article is founded on the primary data analysis mostly, as the peer-reviewed literature, government reports, publications of the institutions, and environmental assessment of the past decade are reviewed. MOEFCC (Ministry of Environment, Forest and Climate Change, 2011), CGWB (Central Ground Water Board, 2019), NRSC (National Remote Sensing Centre, ISRO, 2011), local fisheries reports, and the surveys of IUCN (International Union of Conservation of Nature) and WWF-India (World Wide Fund for Nature - India) are the most crucial resources that include the information on hydrology, biodiversity, socio-economics, and policy.

a. Hydrological Evaluation: Lake hydrology had been evaluated through ground water extraction, inflows, outflows and variation of rain falls. The methods used to estimate recharge and water yield and irrigation impacts were Waters-Table Fluctuation and Chloride Mass Balance, which are compared to historical storage and monsoon patterns (Singh and Panda, 2012; CGWB, 2019).

b. Water Quality and Eutrophication: The assessment of the risks of nutrient loading, pollution, and eutrophication was based on secondary data on dissolved oxygen, BOD, nitrates, phosphates, and total dissolved solids, which was put into perspective with other freshwater lakes in India, such as Chilika and Loktak (Tak & Jodha, 2024-25; Sharma and Kansal, 2013).

c. Biodiversity Evaluation: IUCN survey and ecological survey were analyzed of fish, avifaunal and aquatic plant diversity including invasive species, decline in native species and changes in habitats due to human activity (Dubey, IUCN-WCPA; Raza, Tehsin, 2003). The conservation priorities were derived by extracting patterns of species richness, population dynamics and trophic interactions.

d. Socio-Economic Dependence: house hold survey and local government data are synoptized having community dependence on fisheries, irrigation and tourism and their impact on the ecosystem (Verma et al., 2015; Ghosh et al., 2006).

e. Threat and Governance Assessment: Government reports and National Green Tribunal (NGT) rulings and remote sensing data were assessed to explain the illegal mining in the area, shoreline invasion, and changes in land use, and climate variability. The policy interventions, governance structures and participatory co-management were assessed in a manner of educating adaptive management, zoning and participatory governance (Ostrom, 1990; UNESCO, 2018).

f. GIS based Land Use and Hydrological Monitoring: Use GIS and NRSC-ISRO satellite images (2010- 2024) to examine the land-use change, shoreline erosion (reported to be about 8-10% of water spread), catchment degradation and vegetation cover of Jaisamand Lake which would offer spatially explicit data to be used in the hydrology and biodiversity assessment.

Literature Review

Wetlands are fertile ecosystem, which offer biodiversity, water purification, flood control, carbon storage and controlling of the hydrological balance (MEA, 2005**).** There are various wetlands in India, and their destruction by the human factor and climate change has become a widespread problem (Junk et al., 2013; Bassi et al., 2014). This is of great concern to the fresh water lakes of semi-arid regions like Rajasthan where the rainfall, overexploitation, and evaporation are the major threats. Jaisamand Lake in Udaipur is hence a significant example that can be used to explore problems of wetland conservation.

The ecological significance of the Jaisamand Lake is attributed to the fact that the lake supports endangered species which include Mahseer (Tor tor), Indian Skimmer (Rynchops albicollis) and Sarus Crane (Grus antigone) (Raza and Tehsin, 2003). The unpredictable nature of the monsoon rain and the intolerable temperature are associated with semi-arid weather and make the ecosystem vulnerable and affect fisheries, biodiversity of water and riparian plants (Singh et al., 2017).

Hydrological literature underlines unsustainable water consumption as one of the issues. Over-exploitation of groundwater to irrigate crops has decreased the water table causing a decrease in the lake inflows and live storage (Singh & Panda, 2012). According to CGWB (2019), the catchment recharge is significantly lower than the demand of water. Despite spatial variations in the nutrient levels, Sharma and Kansal (2013) emphasize the importance of constant monitoring to identify the risk of contamination at an early stage.

One of the threats is water quality deterioration and eutrophication. Summer and post-monsoon seasons lead to elevated BOD, TSS, nitrates, and phosphates, which encourage algal grows and oxygen reduction, which adversely affect fish and planktons (Tak and Jodha, 2024-25; Wetzel, 2001). The experiences of Dal and Loktak lakes show that the ecological resilience can be recovered through the regulation of the nutrients and management of the catchments (Reddy, 2005).

The invasion of Oreochromis mossambicus (Tilapia) has been biological to a large extent, which replaced the native fish population by Catla, Rohu and Mrigal (Sugunan, 1995; Dubey, IUCN-WCPA). The same trend in Indian reservations shows that there is need to have ecosystem and participatory fisheries management as it has well been proven in the Chilika Lake (Ghosh et al., 2006).

Illegal mining and deforestation have led to degradation in the catchment area which has enhanced sedimentation and decreased water-holding capacity (Walling, 2006). It has been suggested that afforestation and soil conservation are some of the catchment treatment steps that can be taken to reduce such effects (Kothyari, 2000).

It is also socio-economically dependent on the lake and this makes it harder to conserve it. Fisheries and irrigation supporting about 2,500 households and livelihood insecurity usually motivates overuse of the resource (Verma et al., 2015). It is indicated that, participatory co-management enhances compliance, and ecology (Ostrom, 1990; Ghosh et al., 2006).

The discontinuous governance is a significant weakness. International examples of reduced inflows of nutrients due to integrated basin-level planning have been seen in case of Lake Biwa, Japan (Biswas, 2008; Nakamura & Rast, 2011**).** The formation of a special lake authority to Jaisamand may enhance the coordination and accountability.

There is also the pressure of climate change in the form of increasing temperature levels and unpredictable rainfall, which causes water supply and stability in the ecosystem (IPCC, 2021; Guhathakurta et al., 2020).There is therefore a need to integrate climate projections and catchment restoration as well as water management to maintain ecological flows and biodiversity in Jaisamand Lake.

According to the recent studies on the remote sensing of wetlands carried out in India (NRSC, ISRO, 2011; Lillesand et al., 2015), over the last 20 years, wetlands in semi-arid areas such as Rajasthan have lost 10-15% of their surface areas due to the anthropogenic pressures and climate changes. GIS and satellite images allow the invasive species growth, determining the eutrophication hot spots, mapping the habitat fragmentation, and tracking the shoreline and catchment transformations, which are necessary spatial information to be used in designing strategies addressing the lake management effectively and adaptively.

Result and Discussion

1. Water Quality and Hydrological Status of lake

Water management is a vital element that has an impact on the ecological balance of Jaisamand

Lake. The hydrology of the lake is directly connected to the groundwater run-offs in its catchment area where the over-pumping of groundwater to irrigate the agricultural fields has become the greatest menace to ensuring a balanced water regime in the lake (Singh and Panda, 2012).

Recent hydrological researches of the upstream watershed of Gangeshwar that contributes much to the lake inflow used the Water Table Fluctuation and Chloride Mass Balance techniques to determine groundwater recharge and specific yield. The results show that the demand in agricultural waters is almost seven times that of recharge of groundwater every year, which leads to the active decrease of the water table and a decrease in the inflows into the lake, especially in the dry season (CGWB, 2019).

These difficulties are enhanced by the fact that the hard-rock aquifers of the area are fractured and heterogeneous leading to spatial variability of recharge which is estimated to range between 24.3mm and 31 mm per annum. Even after years of high fertilizer application in the adjacent farmlands, in 2012-2014, the studies showed traces of nitrates and potassium in the ground water, which means that the transfer of nutrients is limited (Sharma & Kansal, 2013). Electrical conductivity measuring, nevertheless, provides close to real-time detector of early signs of chloride contamination.

The biggest issue is that there is no systematically collected surface water quality data of Jaisamand Lake. Previous experiences in the other Indian wetlands indicate that agricultural runoff and untreated sewage usually cause eutrophication, high biological oxygen demand, and high organic carbon. To avoid such degradation, there is need to continuously monitor catchment-scale and surface water quality of Jaisamand Lake.

2. Threats to the Ecosystem

2.1 Invasive Species and Native Biodiversity (Tilapia Dominance) Decay.

Jaisamand Lake is threatened by the invasion of the Oreochromis mossambique (Tilapia). The high reproduction rate, low oxygen tolerance and ability to be adapted to degraded water has enabled Tilapia to dominate 50-60 percent of fish biomass at the expense of native species such as Catla catla, Labeo rohita and Cirrhinus mrigala (Dubey, IUCN-WCPA; Sugunan, 1995; Bijoy Nandan et al., 2012). This hegemony interferes with food webs, undermines co-operative fisheries and creates loopholes in governance, which jeopardizes stability in the ecosystem over time.

2.2 Water Extraction and Depleted Hydrological Regime.

Hydrology of lakes has been changed due to excessive extraction of water to satisfy urban and irrigation demands. Diversions to supply Udaipur had been 15-20 million cubic metres a year since the 1980s and lowered live storage, and by the 1990s, nearly dead stored the lake. This has an impact on the breeding of fish, recharging of ground water and vegetation along the shoreline. Unpredictable monsoons and semi-arid climate, worsen the evaporation and ecological loss (Molle & Mollinga, 2003).

2.3 Water Contamination and Eutrophication.

Jaisamand Lake is threatened by water pollution and eutrophication, Agricultural runoff, domestic runoff and waste, and rituals contain reduced dissolved oxygen and elevated the levels of Biological Oxygen Demand (BOD), Total Dissolved Salts(TDS), and nitrates, phosphates, and low dissolved oxygen, which damages the fish and zooplankton species and food chain (Tak and Jodha, 2024-25). Prolonged nutrient additions increase algal growth rates, reduce resilience in an ecosystem, and undermine fisheries productivity and use of water (Wetzel, 2001; Mitsch, and Gosselink, 2015).

2.4 Catchment Degradation and land-use change.

Deforestation, farming and settlement activities have augmented run-offs, erosion and sedimentation, lowering the depth of the reservoirs and quality of aquatic habitats. The siltation has destroyed water breeding habitats and the diversion of recharges has undermined groundwater regeneration. Patterns in other Indian lakes support that the degradation of catchment affects the water quality and trophic structures (Jaisamand Wildlife Sanctuary Management Plan; Chowdhury & Tripathi, 2019; Reddy and Char, 2006).

2.5 Pressure: Anthropogenic Livelihood Dependence and Encroachment.

The encroachment of settlements and extraction of resource menaces the sensitive littoral areas that are essential in breeding of fish and birds. The loss of fish species has lowered revenues of fishermen, which has led to overexploitation and strengthened ecological deterioration. These pressures are further exacerbated by weak governance and absence of participatory management which harms ecosystem health as well as local livelihoods of people (Viren Lobo; Ostrom, 1990; Dubey, IUCN-WCPA).

3. Sustainable Management Practices

3.1 **Invasive Species control and Restroring native fish.**

The control of Oreochromis mossambicus (Tilapia) is important in restoring the ecological balance in the Jaisamand Lake. Tilapia, which is 50-60 percent of the fish biomass, replaces native carps, including Catla catla, Labeo rohita, and Cirrhinus mrigala (Dubey, IUCN-WCPA; Sugunan, 1995; Bijoy Nandan et al., 2012). Some of these strategies are selective harvesting, minimal exotic stocking, and gradual replenishment of native species. Decreased biodiversity of the Chilika Lake was reversed through community-based fisheries, fishing prohibition and equipment curtailment, which have been employed in 10 years (Ghosh et al., 2006; FAO, 2011). The invasive dominance can be reversed with gradual efforts by the fisheries departments, cooperatives, and ecologists so that the local livelihoods are not compromised.

3.2 Environmental Flow and Controlled Water Withdrawal from lake

Massive diversion to urban supply creates an imbalance in the hydrology, causing a decrease in live storage and fish breeding and vegetation cover on shorelines (Agarwal and Narain, 1997; Molle and Mollinga, 2003). Essentially 30-40 per cent of the drinking water of Udaipur was historically supplied by Jaisamand, which led to prolonged drawdown. There are concepts of environmental flow (e-flow) that establish the lowest possible water levels in which ecosystems operate (Smakhtin et al., 2004). The pressure can be decreased by regulated withdrawals, collection of rain water, and other water sources to enhance the ecological balance.

3.3 Catchment Area Treatment and Mining Regulations.

Catchment health influences the sediment inflow, the water quality and storage. Unlawful mining, deforestation, and soil erosion enhance siltation and decrease the capacity of the reservoirs (Walling, 2006; Jain et al., 2010). Catchment Area treatment (CAT) like afforestation, contour bundling and check dams may reduce inflows of sediments by 30-50% (Kothyari, 2000; World Bank, 2018). A combination of CAT approach with remote sensing, tight control, and involvement of community improves resilience.

3.4 Nutrient Management and pollution control.

A high BOD, TSS, nitrates and phosphates reveal agriculture, domestic effluents and rituals (Tak and Jodha, 2024-25). Eutrophication decreases light penetration and oxygen, causes harm to the aquatic life (Wetzel, 2001). The restoration of a water quality and fisheries productivity can be achieved using integrated interventions such as sewage interception, constructed wetlands, vegetated buffers, low-input farming, and control of fertilizer (Reddy, 2005; CPCB, 2018).

Zonation and Shoreline Control 3.5.

The littoral areas are very sensitive areas where fish breed and birds nest (Wetlands International, 2010). Habitat loss and pollution are the effects of unplanned settlements and land-use changes (Viren Lobo). The stress of the shoreline can be mitigated through participatory management, legally demarcated 50-100 m buffer zones, geospatial mapping, and alternative livelihoods to restore the biodiversity (Ostrom, 1990; Ramsar Secretariat, 2016; Ghosh et al., 2006).

3.6 Climate Change Adaptation
The increased evaporation, rising temperatures, and unpredictable precipitation constitute a threat to the hydrology of lakes (IPCC, 2021; Guhathakurta et al., 2020). Hydrological resilience can also be enhanced by 25-40 percent using climate-resilient management (catchment afforestation, feeder stream restoration, micro-wetlands, and reduction of evaporation) (Bates et al., 2008; World Bank, 2018).
3.7 Co-management and participatory governance represent a kind of management in which managers interact with employees, thereby fostering trust, motivation, and commitment to their work.
Co-Management and Participatory Governance Co-management and participatory governance is a form of management where managers and employees relate to each other and hence achieve trust, motivation and commitment to their duties.
Lack of involvement of local communities makes the use of the resources unsustainable (Ostrom, 1990). The co-management of the Chilika Lake minimized illegal fishing and more fish were caught (Ghosh et al., 2006). The adherence, fairness, and sustainability in the long term ecologically are enhanced by lake-level committees consisting of fisher cooperatives, panchayats, and forest officials (Tak & Jodha, 2024; Ramsar, 2015).
3.8 GIS and Remote-Sensing Surveillance.
Remote sensing determines a change in land-use, shoreline dynamics, water dispersal, and vegetation health (Lillesand et al., 2015; Jensen, 2016). Mapping indicates that NRSC-ISRO reveals the areas of wetlands shrinkage and pollution hotspots. Through the combination of satellite data and field data, it is possible to not only identify stress early and adaptive management can be managed with evidence (Tak et al., 2024).
3.9 **Integrated Lake Basin Management.**
Weak conservation is caused by fragmented governance (Biswas, 2008). The basin level of IWRM coordinates land use, water allocation, water pollution control and biodiversity preservation. Integrated management decreased the nutrient inflows by more than 50 percent in one of the lakes, Lake Biwa, Japan (Nakamura and Rast, 2011). The ecological goals in the development plan of Jaisamand can be entrenched in a statutory Lake Authority and advisory committees.
3.10 Eco-Tourism and Lived In diversification.
The degradation of ecosystems compromises the livelihoods of people. Resource pressure is minimized by livelihood diversification (Berkes et al., 2000). With the help of Ecological integrity and increasing community stewardship we may get controlled boating of lake, controlled fishing, eco-tourism, waste management, and alternative livelihoods like handicraft or guided tours (UNEP, 2012; Kumar and Raj, 2018).
3.11 Adaptive Lake Management based on GIS.
Implement GIS-based surveillance and mapping to locate and mitigate critical areas of invasive species removal, implement 50-100 m shoreline buffer areas, implement priority interventions to treat catchment to support evidence-based, adaptive, and spatially-informed management of ecological health and biodiversity of Jaisamand Lake.
Key Findings of Jaisamand Lake Study
a. Hydrological Stress: Over-pumping of groundwater sources to service domestic and economic demands has decreased the availability of groundwater, inflow to lakes, and interference with the regular cycle of groundwater (Singh and Panda, 2012; CGWB, 2019).
b. Invasive Species Dominance: Native fishes such as (rohu, Catla, rohita, mrigala) are in competitive with Oreochromis mossambicus (Tilapia) that makes approximately 50 to 60 percent of the total fish biomass (Sugunan, 1995; Dubey, IUCN-WCPA).
c. Loss of Biodiversity: Native fishes (rohu,catla) and aquatic plants and birds are also becoming rare (endangered in IUCN category) because of habitat disturbance and destruction,

invasive species pressure, and changes in strong-weak interactions.
d. Eutrophication & Nutrient discharge: Agricultural fields runoff and effluents, domestic sewage and runoff, and religious activities have reduced dissolved oxygen and enhanced the levels of Biological Oxygen Demand, Total Dissolved Salts, nitrates, and phosphates leading to algal proliferation, oxygen depletion, and disruption of food chain and web (Tak & Jodha, 2024).
e. Catchment Degradation: Deforestation, land-use change, and underground mining have amplified the inflow of the sediment, decrease the water retention, diminished the benthic habitat, and water quality (Walling, 2006; Chowdhury & Tripathi, 2019).
f. Encroachment Pressure: Settlements in littoral areas have caused the loss of habitats, loss of shoreline, litter accumulation and disturbance of fish spawning and nesting sites as well as bird nests.
g. Socio-Economic Vulnerability: Fisheries, tourism, and irrigation are a source of livelihood to almost 2,500 households, which makes them highly reliant on ecological degradation (Verma et al., 2015).
h. Climate-Driven Risks: Hydrological stress and ecosystem susceptibility are increasing with an increase in temperature, fluctuation of rainfall, and an increase in the rate of evaporation (IPCC, 2021; Guhathakurta et al., 2020).
i. Poor Ecological and Water quality monitoring: The management deplores poor ecological and water-quality surveillance resulting in even more pollution, eutrophication, species invasion, and habitat destruction.

Limitations and Research Gaps

Although there is extensive secondary information in the last ten years, it is apparent that very little is known about the ecological and socio-economic dynamics of Jaisamand Lake. The majority of the studies are focused on single elements, e.g., the quality of water, hydrology or fish variety, making the knowledge look like a puzzle. The transformation of surface water, nutrient loading and pollutants is poorly monitored over a long period, thus preventing the detection of fluctuations in eutrophication and episodic pollution (Sharma and Kansal, 2013).
The use of biological measurements is also not adequate, especially on macroinvertebrates, planktons and submerged vegetation, which support food webs and ecosystems resiliency. Despite the recorded dominance of Tilapia, there is a lack of empirical research on the restoration of native species and alterations in the trophic interactions.
Socio-economic aspects are ill-researched. The lack of knowledge on fisher livelihood and resource dependence, as well as local ecological perceptions, hinders the participation management (Ghosh et al., 2006). Existing studies of groundwater surface water interaction, land-use change and climate variability are obsolete or space restricted and less predictive. Legal mining, deforestation and soil erosion effects on catchment affecting sedimentation and water quality are not consistently recorded and are seldom geospatially incorporated.
To ensure these loopholes are filled, academic and government institutions ought to conduct pertinent research to help in the conservation that is evidence-based (Sharma and Kansal, 2013). Lake management requires informed and participatory management where complex biological surveys are carried out on other than fish, long-term population surveys, systematic water-quality surveys, and specific socio-economic surveys (Singh and Panda, 2012).

Conclusion

Natural and human influences that determine the ecological health of Jaisamand Lake are: hydrological variability, catchment degradation, invasive species, pollution and unsustainable resource exploitation. Overuse of groundwater to irrigate farmlands and feed urban areas, uncontrolled mining activities and changes in land use have changed the hydrology of the lakes, diminishing the live storage, impairing groundwater recharge and disrupting aquatic and riparian ecology (Singh & Panda, 2012; Molle and Mollinga, 2003). The native fish has been displaced by the invasion of Oreochromis mossambique (Tilapia) and has caused a disturbance in trophic interactions, as well as posing a threat to biodiversity and fisheries-based livelihoods (Sugunan, 1995; Dubey, IUCN-WCPA). The agricultural runoff, sewage, and ritual activities have provided nutrients that have accelerated the rate of eutrophication, decreased the dissolved oxygen, and lowered the aquatic productivity (Tak & Jodha, 2024-25; Wetzel, 2001).

Nevertheless, in spite of these strains, Jaisamand Lake still benefits the biodiversity and local communities.Controlled water abstraction, preservation of the environmental flow, control of invasive species, restoration of catchment, nutrient management, and zoning of the shoreline are sustainable management methods that need to be employed together (Agarwal and Narain, 1997; FAO, 2011; Ghosh et al., 2006). The relevant policy should be participatory governance and cooperation between fishers, forest authorities, researchers, and local institutions, which are crucial for sustainability in the ecological and livelihood context in the long term (Ostrom, 1990; Tak and Jodha, 2024**)**. Continuous monitoring, early identification of stress and adaptive management can be achieved with the help of GIS and remote sensing (Lillesand et al., 2015; NRSC, ISRO).

To achieve sustainable future of the lake, it is important to balance the development pressures and the ecological integrity. Placing research, institutional coordination, implementation of policies and community participation in a more integrated setting can save biodiversity, enhance water quality, and enhance livelihoods. Evidence-based, adaptive management can be essential in filling the knowledge gaps in the areas of biodiversity, hydrology, pollution, and socio-economic interactions to guarantee the long-term viability of Jaisamand Lake (Mitsch et al., 2015; UNESCO G-WADI, 2018).

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