

Journal of Biological and Chemical Research



An International Journal of Life Sciences and Chemistry
EISSN 2319-3077 (Online) | ISSN 0970-4973 (Print)

www.jbcr.co.in | jbiolchemres@gmail.com



Journal Impact Factor: **4.275**, | Global Impact Factor: **0.876**, | InfoBase Impact Factor: **3.66**
Scientific Journal Impact Factor: **3.285**, | IC Value: **82.43**

Scope

Life Sciences (Botany and Zoology), Medical Sciences, Chemical Sciences, Agricultural Sciences, Biochemical Sciences, Environmental Sciences, Biotechnology, Molecular Biology and Tissue Culture



Volume 43 (1), January-June, 2026



Indexed, Abstracted and Cited

Index Copernicus International (Europe), Research Bible (Japan), Scientific Journals Impact Factor Master List, Directory of Research Journals Indexing (DRJI), Indian Science. In, Database Electronic Journals Library (Germany), Open J-Gate, J Gate e-Journal Portal, Info Base Index, International Impact Factor Services (IIFS) (Singapore), Scientific Indexing Services (USA), International Institute of Organized Research (I2OR), World Cat, International Innovative Journal Impact Factor, Swedish Scientific Publishing, Eye Source and cifactor.org Journals Indexing Directory, Cosmos Science Foundation South-East Asia, Indexing of International Research Journals and ImpactFactor.pl - Compendium wiedzy o czasopismach naukowych, Philadelphia.



Dr. Arshad H. Rizvi

REVIEW ARTICLE

Received: 14/04/2026

Revised: 26/05/2026

Accepted: 27/05/2026

Conserving Freshwater Ecosystems in India: Threats, Governance, and Management Approaches: A Review

Arshad H. Rizvi and Mohd. Zahid Rizvi

Department of Botany, Shia P.G. College, Lucknow, U.P., India

ABSTRACT

The growth of human civilization has enhanced the disturbances within environment. Various activities essential for development are such that they interfere with the normal functioning of ecosystem. Although we say that industrialization and commercialization are significant for the developing countries of the world, the pressure has simultaneously increased over the natural resources of which fresh water, bear most of the impacts. The third world countries especially India needs to focus on the conservation and utilization of her rich aquatic resources which are available in the form of perennial rivers, lakes, springs, ponds and streams. The present chapter is a review on the significant usage of such a natural resource in limited quantity and highlights the threats and problems associated with aquatic resources all over the world with special reference to India. It also focusses upon the consequences if it is not been taken care of in terms of quality and quantity. This review incorporates several fresh water management strategies that are being opted all over world for aquatic resource management. Such strategies and management practices shall be applicable to the tropical fresh water management in India as well so that the consumption for developmental activities, simultaneous industrialization and increasing population demand can be balanced and this natural resource can be utilized economically for sustainable development.

Keywords: Freshwater ecosystems, Freshwater conservation, Eutrophication, Ecosystem restoration, Aquatic Habitats.

INTRODUCTION

The recent approaches have shown serious concern towards the need for water resource management. Water is the most significant factor of the biosphere as it regulates many geological processes as it sculpts, alters and creates landforms while wearing away mountains thus acting as essence of life on earth. Globally the freshwater bodies are considered as the 'life-blood' of human civilization. Human settlements in ancient times were located adjacent to rivers and lakes. It showed the dependency of human civilization on adequate water supplies. With increasing population, water resources were utilized for

several different purposes and the need for proper management of water bodies all over the world was realized.

Fresh water biodiversity inculcates variety of life from freshwater, brackish and marine ecosystems. Man depends heavily on aquatic biodiversity for food, trade and other essential commercial and industrial entities. The value of aquatic biodiversity rates very high in present-day economic policies (Ahmed et al., 2022).

Freshwater diversity is vulnerable to the impacts of anthropogenic activities catchment-wide and the changes which are irreversible in nature and give rise to long term significant ecological alterations (Dudgeon et al., 2025). Today's scenario indicates that several factors like pollution, destruction, habitat alteration, over-exploitation or introduction of alien species are among the most threatening impacts to the biodiversity of aquatic systems.

An appropriate strategy for conservation and policies has to be drafted to protect the aquatic biodiversity for sustainable development. The conservation with scientific and technical innovations will attend to the present problems in protecting aquatic biodiversity and the sustainable use of understanding the interdependence of ecosystems on organisms and human needs in the present-day scenario.

In aquatic ecosystems, biotic changes and environmental disruptions due to natural hazards restrict the ability of aquatic resource managers to maintain biodiversity and restore the original ecosystem functions. They should identify such areas as catchment hydrology and aquatic terrains where originality of ecological setup can be maintained by framing laws, policies and conservational efforts to ensure their restoration, protection and as basic resources for fresh water research.

Significance

More than two-third of the earth's surface is covered with fresh water like oceans, glaciers, rivers and lakes. Out of total world's water volume, 97.5 % is saline and oceans contain approximately 99.9 % whereas remaining constitutes the salt lakes. On the global scale non-saline water volume is only 2.5 %. Total fresh water constitutes 75 % locked up as ice-caps and glaciers and 24 % exist as ground water. Thus, freshwater found in lakes, rivers and as soil water reservoir is less than 1 % of the total (Hancock and Skinner, 2000). Human activities have modified the world ecosystems to varying extents. Some were purposefully altered to meet the human requirements like clearing of forests utilized for agriculture, rural and urban settlements. Man's exploitive activities have reached to its maximum limit. Deforestation, construction of industrial plants, dams and highways and wastes dumping significantly deteriorate terrestrial systems and also dump wastes to nearby water bodies and alter biodiversity after entering directly or through rain drainage.

Global scenario

Fresh water biodiversity is of vital importance to all life forms on earth especially humans and their dependency is shown in form of trade, health industries, domestic consumption and especially food production (Postel and Carpenter 1997; Gleick 2001). Only 2.3 % of total earth's water is fresh which inhabit a large biodiversity of terrestrial and aquatic nature. Wetlands, roughly occupy 6.4% of the earth's surface. Of those wetlands, bogs constitute 30%, fens 26%, swamps 20%, and flood plains 15% (Lianthuamluaia et al., 2021). Lakes occupy even less than 0.007% of world's fresh water (Clarke, 1994). Rain and snowfall replenish this fresh water every year. Water is required for various purposes like domestic usage, fisheries, navigation, agriculture, industrial production, hydropower generation and recreational activities. Wetlands such as marshes, peat land, swamps, bogs, open water

bodies like lakes and rivers, mangroves, tidal marshes, are being used by humans to fulfil their requirements and for environmental amelioration. Increasing population, urbanization and industrialization have accelerated serious environmental threats on these ecosystems and have affected them to such an extent that their benefits have declined significantly (Abuthagir Iurahim et al., 2023).

Indian Scenario

Tropical freshwater systems constitute springs, wetlands, perennial rivers, lakes, and other reservoirs specially of Indian sub-continent which are rich in biological diversity. Here the role of climate is the significant determinant of species composition and distribution pattern. A number of factors including colonisations, species introduction and interactions, productivity, micro-habitat heterogeneity, natural and anthropogenic perturbations control compositional variability on local and regional scales (Dodds, 2002). Such factors jointly determine not only the composition and distribution of aquatic species but also the changes from aquatic through marshy to mesotrophic communities.

India supports a rich diversity in inland and coastal areas basically due to its geological area, topography and climate. Major river systems in the north are Ganga, Yamuna, and Brahmaputra and in the south, Krishna, Godavari, and Cauvery. There are 67,429 wetlands in India, covering about 4.1 million hectares. Out of these, 2,175 are natural wet lands covering 1.5 million hectares of area and 65,254 are artificial wetlands occupying about 2.6 million hectares of open area.

Forest Survey of India showed that mangroves cover 6,740 sq km of the area. They are Sunderbans and Andaman and Nicobar Islands which cover 80% of the country's total mangroves. The rest are in Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujarat, and Goa. Wetlands have been altered by anthropogenic activities like unchecked and unplanned urban and agricultural development, road construction, industries, impoundments, resource extraction, causing substantial economic and ecological losses in the long term. Out of 58.2 million hectares of these, 40.9 million hectares are under paddy cultivation. 3.6 million Hectares support fish culture and 2.9 million hectares are under capture fisheries (brackish and freshwater). Mangroves, estuaries and backwaters cover 0.4, 3.9, and 3.5 million hectares respectively of the total area. Man-made reservoirs constitute 3 million hectares and rivers, tributaries and canals cover roughly about 28,000 km. 113,000 km area is covered by Canal and irrigation channels (Rajinikanth, R. and Ramachandra, T.V., 2000).

Wildlife Institute of India's survey indicates a very serious picture of the fresh water marshes and lakes of Gangetic flood plains where 70-80% has been lost in the last five decades. Indian mangroves have decreased by half from 700,000 ha in 1987 to 453,000 ha in 1995. Nutrients washed off from the catchment get deposited to nearby water bodies and wetlands through runoff. The impacts of human activities like vegetation cover removal or disturbed catchment lead to loss of nutrients from terrestrial areas and their gradual accumulation to wetlands (Abuthagir Iurahim et al., 2023). Mine tailings washings from agricultural land in form of P and ammonium alter water chemistry and biology with accelerated growth of algae mostly nuisance species.

Rapid agricultural growth and its future implications will have detrimental effects on non-agricultural terrestrial and aquatic habitats of the world. The agricultural food production doubled during the past 35 years directly associated with a 6.87 times increased use in nitrogen fertilizers, 3.48 times increase of phosphorus fertilizers, 1.68 times increased

irrigated agricultural land and 1.1 times increase in land under cultivation (Tilman, 1999). These projected increases shall have tremendous impacts on the diversity, composition and functioning of natural ecosystems of the world particularly wetlands. This will affect diverse ecosystem services available for the humans. Such effects may convert inland water bodies into a polluted and eutrophied mass. Eutrophication of such aquatic habitats may lead to acute biodiversity decline, outbreaks of nuisance alien taxa, alteration of food chain structures and loss to fisheries. Direct inputs of industrial effluents and urban sewage accelerate eutrophication rates.

Many serious water-borne diseases in humans spread through aquatic vectors. The outbreak of water-borne diseases is accelerating as disease vectors easily dispersed through poor water management and pollution as direct or indirect consequence of changing biodiversity. Anthropogenic interventions in freshwater systems reduce natural biodiversity and favour only few species that can often become nuisance according to geographical boundaries. Clean and safe fresh water is a limiting resource for developing nations of the world. Hence the role of biodiversity in freshwater systems is significant for sustaining goods and services for human settlements. Freshwater systems are linked with cultural, aesthetic and spiritual values. Age old Beliefs, offerings and sacred grooves are strongly associated with natural freshwater areas and their endemic biota (Ahmed et al., 2022). Also the psychological and recreational contributions provided by natural freshwater systems such as boating, fishing, rowing, rafting and creativity depicted in painting, music, and poetry are immense. Freshwater biodiversity supplies essential entities and services to human population's including Commercial, recreational sports, game fishing and wild life hunting (Dudgeon et al., 2025). It also acts as supplier of nutrients and carbon sources to sustain terrestrial land marine productivity. Aquatic faunas are highly endemic such as flocks of fishes in ancient African lakes. Other aquatic taxa like fish and bivalves get isolated within river or lake catchments providing opportunities for radiative adaptation and speciation. Such endemism makes them more vulnerable to changing conditions and their disappearance is a serious consequence for natural aquatic systems.

Disturbing Impacts on aquatic biodiversity

Most impacts on fresh water systems indirectly affect organisms at various levels by altering their habitat and change in diversity. The most harmful impacts can damage habitat for sensitive species. Habitat alteration may include any combination of the following:

Alteration of natural flow regimes by formation of dams, diversions, and watershed land uses

Aquatic ecosystems receive a continuous input of energy as dissolved organic matter either produced within the water body or imported from terrestrial communities or land-water interfaces. Terrestrial and aquatic ecosystems are linked together by movements of water and materials, through the drainage basin. Any alterations in the natural drainage affect the chemistry of lake and influence the composition of dissolved materials and associated microbiota (Verma, 2004).

Changes in water quality due to point and nonpoint source pollution

Pollution of inland waterways, dredging and filling of reservoirs, Woody debris inputs to streams are some of the non-point sources that increase the inputs to freshwater sources and reduce forest cover along waterways.

Invasive alien taxa

Modification of the natural fresh water and encroachment of the drainage area leads to change in species composition and their numbers. Sensitive species gradually gets replaced

by more tolerant taxa which is not the native one but have encroached upon from nearby areas. This limits the diversity of flora and fauna to only those which can survive and gradually cope up with such kind of changes.

Disappearance of base species sensitive to changes

Destruction of natural water ways by pollution and siltation are some of the major disturbances that have been categorized. Agricultural fertilizers, pesticides, fungicides, sewage, industrial wastes etc. are adding large amounts of nitrogen and phosphorus to aquatic systems resulting in cultural eutrophication. Lakes and reservoirs polluted in these ways have now associated themselves with sea, bay and oceans where they drain themselves.

Over exploitation of aquatic resources, exotic and endemic species

Aquatic plants act as indicators of any change in water bodies as the inputs of nutrients and contaminants by anthropogenic activities can inhibit or stimulate their growth (Pandey and Verma, 2012). The synergistic effect of such changes in the physical and chemical environment amounts to a deterioration in the quality of habitat for native taxa. Species which can tolerate such environmental change dominate aquatic communities, whereas those who are native to those places gradually get extinct. Endemic species are particularly sensitive to these environmental changes, and start disappearing when habitats have been altered extensively. Loss of endemic species and invasion of tolerant species from outside the region erode the unique floral and faunal diversity of the region.

Potential threat to spawning grounds

The wetlands serve as the eco tones between aquatic and terrestrial ecosystems. Wetlands play a significant role in maintaining the diversity of life on earth. They offer suitable habitats for a variety of aquatic life forms.

The wetlands are crucial for recharging the ground water regime and act as natural barriers for floods and erosion. In the recent past, increased biotic pressures have led to loss of flora and fauna from these ecosystems and it has been realized now prior to their understanding in recent times (Lianthumluaia et al., 2021). These fragile ecosystems require a systematic effort to study the flora and their proper assessment for their better understanding and its sustenance for mankind. Aquatic communities are highly productive and they form substantial sinks for carbon and other nutrient storage. In wetlands, they form valuable habitats for variety of breeding winter and migratory birds, invertebrates, amphibians and related dependent wildlife by providing spawning grounds to them. The documentation of aquatic biodiversity is dependent on their niches. It will be more fruitful to conserve biodiversity in their own endemic areas which will provide the necessary information for formulating policies and effective conservational programs (Nath, 2012).

THREATS TO AQUATIC BIODIVERSITY

Habitat fragmentation

Threats to species are due to a decline in the areas of their habitats, fragmentation of the niches and loss of habitat quality. Fragmentation leads to slow and gradual extinction of sub populations decreases the genetic variability due to isolation, restrict their scope of expansion and growth. For aquatic and semi-aquatic species, the declines in habitat quality are due to diversion of ground water, resulting in the drying up of streams and other water bodies, siltation, and water pollution with inputs of pesticides and other chemicals.

Introduction of exotic taxa

Freshwater fish are threatened by the introduction of exotic species which may be competitors or predators. Competition, predation, disturbances in food web levels and

acquired diseases are some of the interferences forced upon native species by these alien taxa. The influence such species is increasing with more usage of sea trade, aquaculture, and global commerce. The species introduced either intentionally or accidentally include different taxa from fishes and higher plants (such as water hyacinth) to invertebrates and microscopic flora (such as dinoflagellates) (Revenga and Kura, 2003).

Drainage area fragmentation

Anthropogenic activities are the most potent source influencing physical, chemical and biological features of standing and running waters worldwide. Direct effects are in form of alteration in water courses and indirect in form of water quality change which result from change in land use and other activities within the drainage area. Extensive human activities within the drainage basins of rivers and lakes cause eutrophication and water pollution (Pandey and Verma, 2008). Anthropogenic impacts are often direct such as construction, excavation, hydrological influences and farming. Further, by removing natural vegetation cover through cutting, burning and grazing, humans have accelerated erosion and sedimentation of water bodies. Indirect activities of man can lead subsidence, landslides and induce earthquakes (Gray, 1999).

Speciesendemism

Man has transformed himself as agent of dispersal for several species beyond their geographical boundaries. The native and endemic species which are very near to extinction have to compete for their own niches from the species which easily flourish in their own new environment.

These species adapt very well and flourish on the resources available and extract as they are protected from parasites, predators and native competitors. These resilient exotic species become a serious threat to native species and give a good competition.

Suspended particulate matter

Concentration of Particulate matter in fresh water resources increase from inputs like Sediment, Fertilizer, other non-point runoff sources, sewage having pathogens and nutrients, chemical spills, garbage dumping, thermal pollution, mine drainage, acid rain, rapid urbanization and habitat destruction. Understanding implication of such alterations requires detail understanding of the water utilization economy. The effect of such human activities on ecosystems is linked across landscapes and also incorporates wet lands, streams, ground water and lakes (Dodds, 2002).

Effluent and sewage loading

In rapidly industrializing countries like India untreated sewage and industrial wastes create substantial pressures on water quality. The economic and aesthetic values of fresh water are lost. For the last decade or so water pollution by effluents and sewage has resulted as serious threat in India as most of the fresh water resources are polluted which have a negative impact on human health and biodiversity. Water pollution control is essential for ecological sustainability of water resources as well as for underlying economic reasons and global impact.

Thermal pollution

Warm water released directly to nearby water bodies have posed a unique threat for aquatic biodiversity. Species sensitive to sudden temperature change reside to different layers accordingly. Fluctuations in temperature lead to mass killings of organisms and quick encroachment of alien taxa which are tolerant high temperature fluctuations.

Increased pollutant loading

Habitat disturbance in form of diversion, damming and channelization, pollution from point and non-point sources are some of the significant threats to the existing fresh water systems (Singh *et al.* 2006). Global renewable supply of fresh waters is about 39,000km³ per year and per capita use about 54% of the runoff which is sufficiently accessible. Hence fresh water is amongst those resources that will be limited severely with future growth of human civilization. Ground water aquifers with recharging potential may become good indicators of high-level pollution by signifying low oxygen conditions and contamination.

Global Climate change and adaptation

Biodiversity of lentic and lotic habitats are very well defined depending on the stratification and zonation, transparency, light penetration and nutrient availability. Rich biodiversity is observed in the wetlands where it supports flora and fauna of both habitats acting as ecotone across spatial gradient with moderate to high primary productivity owing to sufficient sunlight and nutrients (Heino *et al.*, 2008). Here decomposition rates are also high which support a diverse nature of flora and fauna. Species diversity and richness can be observed as high for both land and open water communities. Lotic ecosystems are amongst the most threatened ecosystems as most of the human settlements were established and utilized the water along the river coast making it a dumping site for all kinds of wastes. A rise in average global temperature above 0.7 C during last 100 years has affected the species conservation and changes within the ecosystem.

It differs from region to region and across the continent. Gradual biota depletion affects the "microclimate" which brings about changes in morphology, susceptibility and adaptability of species making some of them more resilient than others. Significant biota has been already extinct and others are threatened due to unwanted human interference and habitat destruction.

Disturbances in linkages between aquatic biodiversity and ecosystem functioning

Phytoplankton diversity is a major part of food chain in aquatic ecosystems. They are very sensitive to anthropogenic inputs of nutrients and toxic substances due to their proliferating nature., phytoplankton act as good indicator of changes in water quality, diversity and ecosystem functioning. An important group of phytoplankton Cyanobacteria, occur in all aquatic habitats and they form pelagic bloom in lakes rich in nutrients. Many bloom-forming species result in foul odors and tastes and cause toxicity to aquatic biota. They comprise of a diverse assemblage of species showing variable dominance in the fresh water system. Some cyanobacteria have the ability to fix nitrogen which is a unique feature of this community and definitely a key factor in the success of these species in N-deficient environments. Moist bank and open water communities' composition have been altered due to anthropogenic perturbations. Such species shift from interfaces and open water may lead to severe habitat impacts and indirectly disturb ecosystem functioning (Pandey and Verma, 2012).

Conservational strategies opted worldwide and management approaches

Biodiversity refers to the variations in the biosphere from lowest to highest level communities and serve as key to ecological balance. Increase in diversity enables more stability of ecosystem through various trophic interactions and steady energy flow (Chatterji, 2011). A number of workers across the globe have suggested different practices related to lake management. Reynolds (1978) suggested that increased loading of P in richer lakes make relatively less impact than mild eutrophication of unproductive lakes. Kronvang *et al.* (1993) monitored Danish lakes throughout the country and suggested that reduced N loading could increase bottom-water oxygen by 0.5-1 %. Several restoration techniques

applied in lakes of Denmark were studied by Søndergaard *et. al.* (2000) and suggested hypolimnetic oxidation and sediment dredging as means for lake restoration and management. It is suggested that a reduction in internal P loading and macrophyte implantation can be useful in early phases of lake restorations. Jeppesen *et. al.* (1990) suggested fish manipulation as a tool for restoration of eutrophic lakes. bio manipulation method as inexpensive and attractive method for management of eutrophic temperate lakes was suggested by Hansson *et. al.* (1998). In a review on resuspension in lakes, Weyhenmeyer (1998) suggested that the flux of resuspended sediment is related to planktonic production and thereby eutrophication and to the degree of water pollution by contaminants. The effects of eutrophication are reversible within limits. Barica (1981) and Søndergaard *et. al.* (2001) observed that sediment dredging and additions of iron or alum reduce internal P loading significantly. Krivtsov *et. al.* (2000) explained a simple stella model as a theoretical base for ecological manipulation and for understanding the environmental relationships. He described its usefulness for theoretical analysis of studies related to terrestrial and aquatic system dynamics, natural resources management, environmental assessment and auditing. Full understanding of internal and external nutrient loading and other limnological features are important for developing suitable practices of lake management (Moss *et. al.*, 1997; Salmaso *et. al.*, 1999; Wade, 1999). Jensen *et. al.* (1994) suggested that the dominance of chlorophytes was more positively correlated with pH than was cyanobacteria. Lewis (1996) in a review on the tropical lakes with respect to latitudinal differences, concluded that though primary production was twice as high, efficiency of energy transfer upto highest trophic level appeared to be low in many tropical lakes. Reynolds and Petersen (2000) elaborated the relation of dominant bloom-forming cyanobacteria distribution being strongly related to the geology of catchments and incidences of significant bicarbonate buffering along with increased P loading in Irish lakes. A review by Jeppesen *et. al.* (2001) on paleo limnology and functional ecology suggested that future expansion of the approaches like use of fossil zooplankton and benthos studies in ecological applications will lead to more precise reconstruction of past environment which might improve the forecast of ecosystem responses to environmental changes and anthropogenically induced perturbations. Pandey and Verma (2004) have suggested that the catchment characteristics influence water chemistry heavily and sediment dredging can act as tool for restoration in dry land lakes. Joy and death (2013) have evaluated the response from resource managers and came to conclusion that they have been insufficient to limit many impacts and have shown a decline of freshwater diversity. Intensification of agricultural and urban encroachment have impact on ecosystem functioning. Dugeon *et. al.* (2006) advocated protection of freshwater biodiversity to be a conservational challenge because it is influenced by the upstream drainage network, topography, the riparian zone, and downstream reaches for migrating aquatic fauna. He was of opinion that attempts to check species loss have been taken in many situations but adoption of a strong position from management side for biodiversity conservation, ecosystem functioning and human earning is required. According to him, 'reconciliation ecology' can be a new term to be introduced for protection and managing biodiversity by balancing development with conservational approaches. Human activities are an important vector for N and P loading. A recent study have indicated that if P and N either can become limiting in shallow fresh water tropical lakes, these limiting conditions can become a tool for lake restoration and reversal of eutrophication to a great extent (Verma, 2015).

Helfrich *et. al.* 2009 has investigated the possible reasons for the decline in aquatic biodiversity. They have observed biodiversity decline as ongoing process and aquatic organisms serve as important indicators of water quality and ecosystem health. They emphasized on requirement of understanding that most species and their surroundings are interconnected and increase the potential of stability and vice versa. Habitat fragmentation, isolation and destruction are the leading threats to aquatic biodiversity. Habitats are being drained, encroached upon at alarming rates. Freshwaters are becoming the most threatened ecosystems and aquatic fauna are at the greatest risk. The disturbances in wetlands are largely the result of human population increase and developmental pressure which have resulted in modification of aquatic landscapes causing significant reduction in aquatic biodiversity (Ahmed et al., 2022).

CONCLUSION

This review has focused on a serious concern regarding the threats and gradual extinction of a large portion of aquatic biodiversity from its local habitats worldwide. The reasons elaborated are extensive and have a rich scope for research and development, especially when they can also be applicable to tropical lake management. It explains severe implications for resource managers and policymakers to focus on and frame policies for their proper conservation and management in the long run.

ACKNOWLEDGEMENTS

The authors are highly grateful to all the researchers who worked on the topic, without whom this review article would not have been possible.

REFERENCES

- Abuthagir Iurahim, S., Rathinam, R. B., Das, B. K., Mishal, P., Lianthumluaia, Ramteke, K., Akash, J. S., & Sarkar, U. K. (2023). Mapping wetland research in India in comparison with the rest of the world (1998–2021): A meta-analysis. *Indian Journal of Fisheries*, 70(4).
- Ahmed, S. F., Kumar, P. S., Kabir, M., Zuhara, F. T., Mehjabin, A., Tasannum, N., Hoang, A. T., Kabir, Z., & Mofijur, M. (2022). Threats, challenges and sustainable conservation strategies for freshwater biodiversity. *Environmental Research*, 214(Part 1), 113808.
- Barica, J. (1981). Hypereutrophy - The ultimate stage of eutrophication. *W.H.O Water Quality Bulletin*, 6: 95-98
- Chatterji, A.K. (2011). *Introduction to environmental biotechnology*. PHI learning Pvt. Ltd., New Delhi.
- Clarke, A. J., (1994). Why Are Surface Equatorial ENSO Winds Anomalous Westerly under Anomalous Large-Scale Convection *J. Climate*, 7, 1623–1627.
- David L. Strayer and David Dudgeon (2010). Freshwater biodiversity conservation: recent progress and future challenges. *J. N. Am. Benthol. Soc.*, 29(1): 344–358.
- Dodds, W. K. (2002). *Freshwater Ecology-Concepts and Environmental Applications*. Academic Press, USA.
- Dudgeon, D. (2010). Prospects for sustaining freshwater biodiversity in the 21st century: linking ecosystem structure and function. In: *Current Opinion in Environmental Sustainability*, Vol. 2: 422–430.

- Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z., Knowler, D. J., Le'Ve'Que, C., Naiman, R.J., Prieur-Richard, A., Soto, D., Stiassny, M. L.J. and Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. In: *Biol. Rev.*, 81, pp. 163–182.
- Dudgeon, D., & Strayer, D. L. (2025). Bending the curve of global freshwater biodiversity loss: What are the prospects? *Biological Reviews*, 100(1), 205–226.
- Gleick, P.H. (2001). Safeguarding our water – making every drop count. *Scientific American* 284: 40-45.
- Gray, R. E. (1999). “Abandoned Mine Lands Ground Improvement Utilizing Coal Combustion Byproducts”, In Proceedings of the 7th Annual Great Lakes Geotechnical and Geo environmental Conference, Kent State University, Kent, OH.
- Hancock, P.L. and B.J. Skinner (2000). *The Oxford Companion to the Earth*, Oxford University Press, U.K.
- Hansson, Lars- Anders, H. Annadotter, E. Bergman, S. F. Hamrin, E. Jeppesen, T. Kairesalo, E. Luokkanen, P. Neilsson, M. Søndergaard and J. Strand, (1998). Biomanipulation as an application of food-chain theory: Constraints, Synthesis and recommendations for temperate lakes. *Ecosystems*, 1: 558-574
- Heino, J., Virkkala, R. and Toivonen H. (2009). Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. *Biol. Rev.* 84, pp. 39–54.
- Helfrich, L. A., Neves, R.J. and Parkhurst, J. (2009). *Sustaining America's Aquatic Biodiversity: What Is Aquatic Biodiversity; Why Is it Important?* Virginia Cooperative Extension programs. Publication 420-520.
- Jensen, J. P., E. Jeppesen, K. Olrick, and P. Kristensen, (1994). Impact of nutrients and physical factors on the shifts from cyanobacterial to chlorophyte dominance in shallow Danish Lakes. *Can. J. Fish. Aquat. Sci.*, 51: 1692-1699.
- Jeppesen, E., M. Søndergaard, E. Mortensen, P. Kristensen, B. Riemann, H. J. Jensen, J. P. Müller, O Sortkjær, J.P. Jensen, K. Christoffersen, S. Bosselmann and E. Dall (1990). Fish manipulation as a lake restoration tool in shallow, eutrophic temperate lakes 1: cross-analysis of three Danish case-studies. *Hydrobiol.*, 200/201: 205-218
- Jeppesen, E., P. Leavitt, Luc De Meester, J. P. Jensen (2001). Functional ecology and palaeolimnology: using cladocerans remains to reconstruct anthropogenic impact. *Trends in Ecology and Evol.*, 16: 191-198.
- Joy, M. K. and Death, R. G. (2013). Freshwater biodiversity. In Dymond JR ed. *Ecosystem services in New Zealand – conditions and trends*. Manaaki Whenua Press, Lincoln, New Zealand.
- Krivtsov, V., E. Bellinger, D. Siegee and J. Corliss (2000). Interrelations between Si and P biogeochemical cycles – A new approach to the solution of the eutrophication problem. *Hydrol. Process.*, 14: 283-295
- Krongvang, B., G. Ertebjerg, R. Grant, P. Kristensen, M. Hovmand and J. Kirkegaard (1993). Nationwide monitoring of nutrients and their ecological effects: State of the Danish aquatic environment. *Ambio*, 22: 176-187
- Lianthuamluaia, Das, B. K., & others. (2021). Status, potential, prospects, and issues of floodplain wetland fisheries in India: Synthesis and review for sustainable management. *Reviews in Fisheries Science & Aquaculture*, 29(1), 1–32.

- Lewis, W. M. Jr. (1996).** Tropical Lakes: How latitude makes a difference? In: *Perspectives in Tropical Limnology* F. Schimer and K.T. Boland (Eds.) pp. 43-64. SPB Academic Publishing, Amsterdam, the Netherlands.
- Moss, B., M. Beklioglu, L. Carvalho, S. Kiline, S. McGowan and D. Stephen (1997).** Vertically-challenged limnology: contrasts between deep and shallow lakes. *Hydrobiol.*, 342/343: 257-267
- Naiman, R.J., Prieur-Richard, A., Arthington, A.H. Dudgeon, D., Gessner, M. O., Kawabata, Z., Knowler, D. J., Le´ve`que, C. Soto, D., Stiassny M.L.J. and Sullivan C.A. (2006).** *freshwater Biodiversity, Challenges for freshwater biodiversity research*. Diversitas, Report N° 5. 48 pp.
- Nath, S.K. (2012).** Aquatic Macrophytes of Laokhowa Wildlife Sanctuary, Assam, India. In: *Int. J. of Engineering Research and Applications* Vol. 2 (5), pp 1911-1013 of the Convention on Biological Diversity, Montreal, Technical Series no. 11.
- Pandey, J. and A. Verma (2004).** The influence of catchment on chemical and biological characteristics of two freshwater tropical lakes of southern Rajasthan. *J. Environ. Biol.*, 25: 81-87.
- Pandey, J. and Anuya Verma (2008).** Ecosystem level Attributes of a Freshwater Tropical Lake in relation to microbial Biomass at Land-water interface. In: Proceedings of "Taal 2007, 12th World Lake Conference", Jaipur, pp.34-43.
- Pandey, J. and Anuya Verma (2012).** The impact of anthropogenic perturbations on moist bank and open water communities at two fresh water tropical lakes of Rajasthan, India. In: *Int. Journal of Environmental Sciences.*, Vol. 3, (no. 1), pp 605-615.
- Postel, S.L. and Carpenter, S.R. (1997).** Freshwater ecosystem services. In: *Nature's Services: Societal Dependence on Natural Ecosystems*, edited by G.C. Daily. Island Press, Washington, DC. pp. 195-214.
- Rajinikant R. and Ramachandra T.V, (2000).** Restoration of Lakes in Bangalore based on Status and Socio-economic aspects of wetlands, Project report, November 2000.
- Revenge, C. and Y. Kura (2003).** *Status and Trends of Biodiversity of Inland Water Ecosystems*. Secretariat.
- Reynolds, C. S. (1978).** Phosphorus and the eutrophication of lakes- a personal view. In: Phosphorus in the Environment: *Its chemistry and biochemistry*. CIBA 57.
- Reynolds, C. S. and A. C. Petersen (2000).** The distribution of planktonic cyanobacteria in Irish lakes in relation to their trophic status. *Hydrobiol.*, 424: 91-99.
- Ricklefs, R. E. and G. L. Miller (2000).** *Ecology*. Fourth Edition, Freeman and Company, New York, USA.
- Salmaso, N., F. Decet and P. Cordella (1999).** Understanding deep oligotrophic subalpine lakes for efficient management. *Hydrobiol.*, 395/396: 253-263
- Singh, J.S., Singh, S. P. and Gupta S.R. (2006).** *Ecology, environment and resource conservation*. Anamaya Publishers, New Delhi.
- Søndergaard, M., E. Jeppesen, J. P. Jensen and T. Lauridsen (2000).** Lake restoration in Denmark. *Lakes & Reservoirs: Res. Manag.*, 5: 151-159.
- Søndergaard, M., J.P. Jensen and E. Jeppesen (2001).** Retention and internal loading of phosphorus in shallow, eutrophic lakes. *The Scientific World*, 1: 427-442
- Strayer, D. L. and D. Dugeon (2010).** Freshwater biodiversity conservation: recent progress and future challenges. *J. N. Am. Benthol. Soc.*, 29 (1):344–358.

- Tilman, D. (1999).** Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. In: *Proc. Nat. Acad. Sci. USA*, Vol. 96, pp 5995-6000. Colloquium paper.
- Vaughn, C. C., (2010).** Biodiversity Losses and Ecosystem Function in Freshwaters: Emerging Conclusions and Research Directions. *Bio Science*, 60(1): 25-35.
- Verma, A. (2004).** "*Environmental impact analysis of anthropogenic activities on a fresh water tropical lake*", Ph. D Thesis submitted to M. L. Sukhadia University, Udaipur (Raj).
- Verma, A. (2015).** Impact of catchment characteristics on nutrient loading of two dry tropical freshwater lakes. In: *Asian Jr. of Microbiol. Biotech. Env. Sc.* Vol. 17, No. (4): 947-951.
- Wade, P. M. (1999).** The impact of human activity on the aquatic macroflora of Llangorse Lake, South Wales. *Aquat. Conserv: Mar. freshwat. Ecosyst.*, 9: 441-459.
- Weyhenmeyer, G. A. (1998).** Resuspension in lakes and its ecological impact – A review. *Arch. Hydrobiol. Spec. Issues Advanc. Limnol.*, 51: 185-200.

Corresponding author: Dr. Mohd. Zahid Rizvi, Associate Professor of Botany, Department of Botany, Shia P.G. College, Lucknow, U.P., India
Email: zahid682001@gmail.com