Thrupthi GN, et al., J Aquac Fisheries 2023, 7: 052
DOI: 10.24966/AAF-5523/100052

HERALD

HSOA Journal of Aquaculture & Fisheries

Research Article

Threats on Aquatic Ecosystem-Mitigation and Conservation Strategies

Thrupthi GN[1]* and Devi Prasad AG[2]

[1]*Research scholar, Department Of Studies in Botany, University of Mysore, Mysuru, India*

[2]*Professor, Department of Studies in Environmental Studies, University of Mysore, Mysuru, India*

Abstract

The immense value of ecosystem service provided by freshwater bodies is incomputable. However, the productivity and biodiversity of freshwater bodies are undergoing degradation as a result of climate- and anthropogenic-induced changes worldwide. There is substantial evidence showing how many freshwater fishes, amphibians, mammals, and reptiles are at risk of extinction. Based on available data the threats can be categorized as existing and emerging. With this categorization, the problems associated with conservation and their solutions vary from one type to another. The mitigation strategies like sewage treatment, use of algicides, use of GIS technology, etc need to be used. The major stakeholders in the conservation are local people, local government bodies, NGOs, and the government. By considering all this there is a need for tailor-made strategies with a combination of traditional and scientific reasoning to conserve the freshwater ecosystem.

This paper puts forth suitable strategies for the restoration of lakes with an overview of traditional, and scientific measures that need to be ensured for successful threat mitigation and conservation.

Keywords: Agrochemicals and nutrients; Aquatic ecosystem; Freshwater ecosystem; Micro and macro plastics

Introduction

Limnology is the study of the structural and functional interrelationships of organisms of inland waters as their dynamic physical, chemical, and biotic environments affect them [1]. The freshwater ecosystem provides services like water for sanitation, agriculture, drinking, and animal husbandry. Of all the water on earth, fresh water accounts for only 3%, nevertheless, the freshwater system is threatened by forces like climate change, overdevelopment, and polluted runoffs [2,3].

Thus, understanding the variation in biodiversity trends in response to biotic and abiotic threats and consolidating the available knowledge is crucial in sustaining the services of freshwater ecosystems [4].

This decade is providing us with a critical opportunity to take action and influence the freshwater biodiversity on the right path. The United Nations Decade on Biodiversity (2011-2020) has ended, allowing governments all around the world to review and analyze their international agreements including Convention on Biological Diversity (CBD), the Sustainable Development Goals (SDGs), and the UN Framework Convention on Climate Change(UNFCCC). A Global Biodiversity Framework is under development, with a mission to "Halt the loss of species, ecosystems and genetic diversity by 2030".

The purpose of this paper is to list the existing and emerging threats to freshwater biodiversity, research, and reiterate the conservation strategies to be employed to overcome the challenges. The paper also lists the mitigation and conservation ideas to combat existing and emerging threats.

Threats to the Freshwater Ecosystem

The threats can be categorized as I. Existing threats and II. Emerging threats

Existing threats due to human activities

Human activities

Anthropogenic activities like deforestation, waste disposal near ponds and lakes, construction of bridges and dams, and agriculture, domestic, and industrial activities result in contamination of the aquatic environment. Human settlements and industries are found to be the major source of water pollution (Table 1). In developed countries, agriculture is the major factor in the contamination of aquatic ecosystems. In developing countries, municipal and industrial effluents are a major threat [5].

Agrochemicals and nutrients

The unsustainable use of agrochemicals (fertilizers, herbicides, pesticides, and plant hormones) has resulted in a greater amount of pollution in the environment [6]. Along with these, agricultural areas gather an extensive amount of agrochemicals from nearby fields due to surface run-off, direct drift, and leaching [7].

When fertilizers are applied at higher concentrations they easily run off and leach into surface water bodies. Even organic manure when used in excess, tends to cause eutrophication and algal blooms, which can cause diseases like blue baby syndrome [5]. Chemical compounds like pesticides, herbicides, insecticides, and fungicides

***Corresponding author:** Thrupthi GN, Research scholar, Department Of Studies in Botany, University of Mysore, Mysuru, India, Tel: +9148809885; E-mail: thrupthinanaiah95@gmail.com

Citation: Thrupthi GN, Devi Prasad AG (2023) Threats on Aquatic Ecosystem-Mitigation and Conservation Strategies. J Aquac Fisheries 7: 52.

Received: February 01, 2023; **Accepted:** March 02, 2023; **Published:** March 08, 2023

Contaminant	Source	Route
Organic pollutants	Domestic sewage, human and animal wastes	Dumped into water bodies or into gutters or drainage where they may get washed into waterbodies
Infectious disease agents	Domestic sewage, human and animal wastes	Washing, swimming or working in irrigated lands
Plant nutrients like Nitrate, Phosphate, and others	Fertilized farmlands, ashes, and detergents	Runoff from farmlands
Pesticides	Organic and inorganic chemicals	Runoff from farmlands
Industrial effluents like DDT, dyes, Mercury, Cadmium, Lead	Textile factories, distilleries, paper mills, food and beverage industries, soap and detergent industries.	Human discharge and mismanagement
Sediments erosion	Deforestation and soil erosion	Urban flooding
Solid wastes	Metals, plastics, artificial fibers	Poor waste disposal

Table 1: List of Existing threats to the freshwater ecosystem.

are extensively used in agriculture and are passed through the food chain until they become toxic to humans [6,8]. Accumulation of salts in the soil causes the salinization of freshwater bodies. The majority of water salinity problems have been reported in countries like China, India, Argentina, and Sudan [9].

Sewage

An estimated 58% of wastewater from urban areas and 81% of industrial wastewater are discharged into water bodies with no or inadequate treatment in contamination of approximately 73% of water bodies [10]. Sewage contains industrial waste, Municipal waste, domestic waste like bath water, washing machine, kitchen waste, and fecal matter. Fresh water sources also serve as the best sink for the discharge of this wastewater [11,12]. Sewage entering into water contains pathogenic organisms out of which 1400 species including bacteria, protozoa, fungi, and viruses have been identified by scientists [13-15].

Many reports of emerging freshwater infections are linked to at least one invasive species, aquaculture intensification, nutrient, and pollutant runoff, or changing food-web structure [16]. Policy changes and improved surveillance have been advocated to decrease the likelihood of pathogen introduction and maximize opportunities for control [17]. In case of infections involving both wildlife and human hosts, or have parallels in transmission control, freshwater management to limit eutrophication, maintain higher trophic levels (e.g. predators), and prevent invasive species could help regulate infections across a range of host taxa.

Heavy metals

Heavy metals like Mercury, Lead, Cadmium, Copper, Zinc, and Nickel are released into the water due to industry and agriculture [18]. Once released in the aquatic environment they bind to particulate matter and settle down into sediments [19].

Designing efficient engineered liners will assist in mitigating groundwater contaminants by acting as a hydrochemical barrier for leachates [20]. The photocatalytic degradation mechanism under visible light irradiation can be used to remove other organic contaminants such as Persistent Organic Pollutants (POPs) and is also used widely for the removal of low-concentrated heavy metal and metalloid ions from solutions [21,22]. Phytoremediation is one of the most used techniques to eliminate heavy metal pollution in ecosystems or environments. It uses raw or genetically modified plant species to minimize the toxic effects of pollutants [23-26].

Eutrophication

Freshwater algae occupy a pivotal position in the food web. Periodically, algal species are selected by environmental and ecological forces allowing their bioaccumulation. These accumulated habitats contribute to climate warming [27], hydrological intensification [28,29], and eutrophication [30]. Once established algal species can reduce Dissolved oxygen, and produce cyanotoxins. These cyano toxins can cause physiological and behavioral impairments in secondary and tertiary consumers [31].

Preventative measures include i) Reducing or removing external nutrient loads [32] ii) aerating lake sediments [33]; iii) chemically treatment of lake sediments to suppress internal nutrient recycling [34]. Mitigation measures include chemical controls like algicides or flocculants, physical controls like increasing flows to reduce water residence time and remove cyanobacteria, and biological controls like introducing organisms that consume algal bloom species [35].

Micro and macro plastics

The larger plastic particles under the influence of environmental conditions degrade into microplastics, typically smaller than 5mm in diameter [36,37]. Microplastics can be ingested by plankton, and fish to birds and can accumulate throughout the aquatic food web [38]. They are also found in human pathogens like specific members of *Vibrio* [39].

Better management of microplastic pollution in fresh waters requires an understanding of (i) sources, sinks, and fluxes; (ii) factors controlling Spatio-temporal variations in microplastic concentrations; (iii) data on co-transported contaminants; and (iv) routes of uptake and effects on freshwater organisms [40]. Legislation to control microbeads has to be implemented. The science supporting mitigation of emerging contaminants such as microplastics lags behind that of pharmaceuticals and personal-care products. Further research is required on what impacts, if any, these materials are having on freshwater ecosystems.

Emerging threats

Changing climate

Climate change is said to threaten approximately 50% of global fish species [41], it is also found to affect phenology, algal bloom, and interspecific interaction [42]. Other threats include an increase in water temperature [43], increased temperature affect species distribution [44], disease outbreak [45], Phenology, and survival [46].

Global government commitments to reduce greenhouse gas emissions [45], expanding freshwater protected areas [47], and mitigation. Habitat restoration for thermal habitat is critical to mitigating the effects of climate change on freshwater biodiversity.

E-commerce and Invasions

Invasive species is a primary threat to freshwater biodiversity and modes of species introduction may develop further in the future [48]. The recent surge in e-commerce linked to internet sales of novel invasive species [49] is an expanding link between established and emerging trade partners. Aquatic weeds are sold internationally through the internet [49,50] and more invasive species are available on major online auction websites [51].

Managing this threat is challenging. The array of mechanisms that can be used are:

I. Using web crawlers to monitor the internet for the sale of plants and animals [52]

II. Authorities can use Artificial Intelligence algorithms to identify the sellers [53].

III. Focusing on accountability and educating buyers with online warning labels and pop-ups [2].

Expanding hydropower

Hydropower dam construction endangers freshwater biodiversity as dams modify natural flow and thermal regimes and decrease river–floodplain connectivity, aquatic productivity, and fish access to spawning and nursery habitats [54,55]. Even when hydropower projects involve fish passage structures to promote movement through dams, such structures may be ineffective [56]. Another major threat associated with Hydropower is river aging and sediment deposition. Sedimentation fragments aquatic habitats, impairs fish health and survival, decreases fish production, lowers primary production, and reduces storage capacity. Altered waterfront access impairs the ability of reservoirs to support other human needs (e.g. food safety, flood control, water supply, and navigation) [55,57].

Shifting the food security of rural inhabitants from aquatic protein to land-based, livestock-derived protein has its own set of socioeconomic challenges. Potential interactions between hydropower and other factors (e.g. climate change, habitat fragmentation) are quite unclear. In the present scenario, hydropower projects are assessed mainly on site-specific and not on their environmental impact. Thus there is a need for a comprehensive EIA that will be unbiased and independent before starting the projects.

Emerging contaminants

Surface waters receive pollution from discharges such as mining, agriculture and aquaculture, pulp and paper production, oil and gas production, and urban runoff. Each of these can impair freshwater biodiversity indirectly by impacting habitat or through direct toxicity. In addition, with improved wastewater treatment across sectors (e.g. municipal effluents) [58], the focus in developed countries is less on addressing acute toxicity (e.g. ammonia) and more on assessing and mitigating longer-term effects from both older legacy and emerging contaminants. More recent studies reveal the effects of other emerging contaminants (e.g. anti-inflammatories, antidepressants) on algal communities [59,60]. Yet, the effects of these individual compounds and their mixtures on aquatic populations and communities, as well as ecosystem function, remain understudied.

Mitigation of emerging contaminants includes advanced treatment of municipal wastewater and reduction of sources [5] – some emerging contaminants (carbamazepine, triclosan, and diclofenac) are more recalcitrant and require the development of novel interventions [61]. Source reductions are effective and necessary for some emerging contaminants given the lack of treatment options, and gains are being made (e.g. reducing the use of antibiotics in livestock production and microbeads in cosmetics in some jurisdictions).

Engineered nanomaterials

Engineered Nanomaterials (ENMs) are manufactured materials (size range 1-100 nm) used in a multitude of industrial, clinical, and consumer applications [62]. ENMs have a high surface-to-volume ratio with unique physical and chemical properties, these properties make them desirable for many applications, however, they can also make these materials bioactivity [63,64]. Nano-pharmaceuticals are an area of intense growth, and the introduction of ENM-enabled drugs or drug-delivery systems into fresh waters warrants careful consideration [65]. Agricultural applications, including fertilizers, herbicides, and pesticides [66], are also a concern.

A major barrier to understanding the risks of emerging ENMs is the lack of sufficient detection and characterization technologies [67]. Current models require more detailed inputs to estimate ENM burdens accurately and to predict risks to freshwater ecosystems. Most available bioactivity data again derive from acute studies on pelagic species, and there is still considerable uncertainty about long-term risks from even the most common ENMs (e.g. titanium dioxide, zinc oxide, silver).

Cumulative stressors

First is the need to resolve whether multiple freshwater stressors simply co-occur, or whether they have interacting effects. Early experimental evidence suggested that some stressor combinations could be synergistic (e.g. high temperature × toxic stress), but in most cases, stressor combinations were less than additive [68]. Data from 88

Threat	Severity of effect	Ecological changes	Degree of understanding	Mitigation measures
Changing climate	Already causing extinction	Alters species size, range, phenology	Moderately understood but highly unpredictable	Global commitments, expand the protected area
E- commerce and Invasins.	Significant role in the trade of non-native plants and animals.	Creates novel modes of long-distance dispersal.	Largely unregulated and poorly understood.	An awareness campaign, and online accountability tool.
Expanding hydropower	Already causing extinction likely to cause more.	The fragments river system inhibits species movement.	Well understood but interactive stressors regulation is unclear.	Proper Environmental Impact Assessment.
Emerging contaminants	Unclear how biodiversity will be changed.	Alters species health and reproduction.	Largely understudied so the impact is less understood.	Improve medication dispersal and better wastewater treatment plans.
Engineered nanomaterials	Unclear how biodiversity will be changed.	Causes minimal acute toxicity in some species.	Uncertainty along the long way of effect.	Improving the detection and characterization, creating targeted formulations.
Cumulative stressors	Contributing to the extinction of species, likely to cause more.	Can magnify impacts and cause ecological surprises.	Poorly understood with a high level of unpredictability.	In need of a multi-purpose solution to protect biodiversity hotspots.

Table 2: List of emerging threats, sources, effects, and mitigation.

papers and almost 300 stressor combinations revealed interactions were most commonly antagonistic (41%), rather than synergistic (28%), additive (16%), or reversing (15%) [2]. A second challenge is to develop methods for diagnosing the relative importance of stressors with combinatorial effects. A possible explanation for the dominance of antagonistic interactions is that those with a large impact might mask or override the effects of lessor stressors [69]. The third challenge is to identify pragmatic approaches to managing multiple stressors impacts.

Riparian solutions offer a smaller-scale alternative, for example, where 'buffer zones' simultaneously influence water quality, protect thermal regimes, provide habitat structure and maintain energetic subsidies, although they are not equally effective for all pollutants [33]. Overall, however, there is a pressing need to understand and address multiple-stressor problems, particularly their impacts on freshwater biodiversity (Table 2).

Conservation Strategies

Traditional methods

1. In ancient times, women were considered the gatekeepers of water ecologies and were responsible for building water bodies like step wells, tanks, and even ponds.
2. Periodic cleaning of water bodies for festivals like Teej and Lasipa (Rajasthan).
3. Tribal practices like irrigation of paddy fields by a network of irrigation canals.
4. Traditional rainwater harvestings techniques like Rajwani and Patali pani.
5. Community ownership of the freshwater ecosystem makes people more accountable for conserving the ecosystem.

Management tools

1. Usage of blockchain-based incentivized computing framework for saving water. This framework facilitates decision-makers in creating awareness among people about water saving efficiently [20].
2. Cloud-enabled Internet of Things (IoT)integration and wireless sensor network is proposed for Precision Soil and Water Conservation Agriculture (PSWCA) through machine learning [71].
3. Using remote sensing and development of Probalistic Support Vector Machines (SVM's) model assisted with the GIS technique to study habitat fragmentation and eutrophication [72].

Conclusion

There are existing and emerging threats to freshwater biodiversity, these threats will increase as the years proceed. To cope with the increasing pressures on water quality and quantity, decision-makers should primarily focus on engineered solutions and their proper implementation. On a local scale, the mechanisms like societal actions (Participation in restoration, dam removal), financial actions (investing in ecosystem services), and fiscal incentives (agri- environmental schemes) need to be taken. A global effort is required to overcome this necessary challenge.

Author Information

Ms. Thrupthi G.N.

Thrupthi G.N. is a research scholar at the Department of stu the es in Botany, University of Mysore, Mysuru. She is working on a Ph.D. in the field of Limnology. Currently, she is also working, as a faculty for the M.Sc Botany course in Jnana Kaveri P.G.Centre, Kaveri. Her area of research includes Physico-chemical analysis of water bodies, and the study of macrophytes, plankton, and fishes.

Dr.A.G.Devi Prasad

Dr. A.G. Deviprasad is a Professor of the Department of studies in Environmental Studies in the University of Mysore, Mysuru. His field of expertise includes plant ecology, biodiversity assessment, natural resources conservation, biodiversity monitoring, plant conservation and conservation biology. He has teaching and research experience of more than 30 years and has guided students with their Ph.D.'s.

References

1. Wetzel RG (2001) Limnology-lakes and river ecosystem (3rd ed.) Elsevier.
2. Reid AJ, Carlson AK, Creed IF, Eliason EJ, Gell PA, et al. (2018) Emerging threats and persistent conservation challenges for freshwater biodiversity. Biol Rev Camb Philos Soc 94: 849-873.
3. Albert S, Destouni G, Duke-Sylvester SM, Magurran AE, Oberdorff T, et al. (2020) Scientists warning humanity on freshwater biodiversity crisis. Ambio 50: 1-10.
4. Dudgeon D (2014) Threats to freshwater biodiversity in a changing world. Freedman B (Ed.), Global environmental change, Handbook of Global Environmental Pollution 1, Springer, Dordrecht.
5. Mateo-Sagasta J, Zadeh SM, Turral H, Burke J (2017) Water pollution from agriculture: A global review. Food and Agriculture Organization of the United Nations, Rome, and the International Water Management Institute on behalf of the Water Land and Ecosystems Research Program, Colombo.
6. Bhat RA, Beigh BA, Mir SA, Dar SA, Dervish MA, et al. (2018) Biopesticide techniques to remediate pesticides in polluted ecosystems. In: Wani KA, Mamta (eds) Handbook of research on the adverse effects of pesticide pollution in aquatic ecosystems. IGI Global Hershey PA 387-407.
7. Rathore HS, Nollet LM (2016) Handbook of pesticides: methods of pesticide residues analysis. CRC Press Boca Raton FL.
8. FAO (2016) The State of World Fisheries and Aquaculture. FAO Rome.
9. FAO (2011) Food and Agriculture Organization of the United Nations (FAO) and London, the state of the world's land and water resources for food and agriculture. Earthscan Rome.
10. Vargas-Gonzalez HH, Arreola-Lizarraga JA, Mendoza-Salgado RA, Mendez-Rodriguez LC, Lechuga-Deveze CH, et al. (2014) Effect of sewage discharge on trophic state and water quality in a coastal ecosystem of the Gulf of California. Sci World 14: 618054.
11. Das J, Acharya BC (2003) Hydrology and assessment of lotic water quality in Cuttack City, India. Water Air Soil Pollut 150: 163-175.
12. Tukura BW, Kagbu JA, Gimba CE (2009) Effects of pH and seasonal variations on dissolved and suspended heavy metals in dam surface water. Chem Class J 6: 27-30.
13. WHO (2006) Guidelines for the safe use of wastewater. Excreta, and greywater. World Health Organization Geneva.

14. Chigor VN, Sibanda T, Okoh AI (2013) Studies on the bacteriological qualities of the Buffalo River and three source water dams along its course in the Eastern Cape Province of South Africa. Environ Sci Pollut Res 20: 4125-4136.

15. CSIR (2010) A CSIR perspective on the water in South Africa. CSIR report no. CSIR/NRE/PW/IR/2011/0012/A.

16. Daszak P, Cunningham AA, Hyatt AD (2000) Emerging infectious diseases of wildlife-threats to biodiversity and human health. Science 287: 443-449.

17. Steinmann P, Keiser J, Bos R, Tanner M, Utzinger J (2006) Schistosomiasis and water resources development: systematic review, meta-analysis, and estimates of people at risk. The Lancet Infect Dis 6: 411-425.

18. Alloway BJ (2013) Introduction: In heavy metals in soils. Springer Dordrecht 3-9.

19. Xu JL, Yang JR (1996) Heavy metals in terrestrial ecosystem. China Environmental Science Press Beijing.

20. Thakur T, Mehra A, Hassija V, Chamoda V, Srinivas R, et al. (2021) Smart water conservation through a machine learning and blockchain-enabled decentralized edge computing network, Applied software computers. Elsevier 106.

21. Abdul-Shukor SA, Hamzah R, Abu-Bakar M, Noriman NZ, Al-Rashdi AA, et al. (2019) Metal oxide and activated carbon as photocatalysts for wastewater treatment. IOP Conf Ser Mater Sci Eng 557.

22. Cheng L, Liu S, He G, Hu Y (2020) The simultaneous removal of heavy metals and organic contaminants over a bi2wo6/mesoporous tio2nanotube composite photocatalyst. RSC Adv 10: 21228-21237.

23. Chibueze C, Chioma A, Chikere B, (2016) Bioremediation techniques-classification based on site of application: principles, advantages, limitations, and prospects. World J Microbiol Biotechnol 32: 1-18.

24. Deb VK, Rabbani A, Upadhyay S, Bharti P, Sharma H, et al. (2020) Microbe-assisted phytoremediation in reinstating heavy metal-contaminated sites: Concepts, mechanisms, challenges, and future perspectives. Microbial Technology for Health and Environment 161-189.

25. Devi P, Kumar P (2020) Concept and application of phytoremediation in the fight against heavy metal toxicity. J Pharm Sci Res 12.

26. Schück M, Greger M (2020) Plant traits related to the heavy metal removal capacities of wetland plants. Int J Phytoremediation 22: 427-435.

27. Elliott JA (2012) Is the future blue-green? A review of the current model predictions of how climate change could affect pelagic freshwater cyanobacteria. Water Research 46: 1364-1371.

28. Huntington TG (2006) Evidence for intensification of the global water cycle: Review and synthesis. Journal of Hydrology 319: 83-95.

29. Trenberth K (2011) Changes in precipitation with climate change. Climate Research 47: 123-138.

30. Downing J (2014) Limnology and oceanography: Two estranged twins reuniting by global change. Inland Waters 4: 215-232.

31. Ferr˜ao-Filho ADS, Kozlowsky-Suzuki B (2011) Cyanotoxins: Bioaccumulation and effects on aquatic animals. Marine Drugs 9: 2729-2772.

32. Paerl HW, Hall NS, Calandrino ES (2011) Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change. Science of the Total Environment 409: 1739-1745.

33. Prepas EE, Field KM, Murphy TP, Johnson WL, Burke JM, et al. (1997) Introduction to the Amisk Lake project: Oxygenation of a deep, eutrophic lake. Canadian Journal of Fisheries and Aquatic Sciences5 4: 2105-2110.

34. Molot LA, Watson SB, Creed IF, Trick CG, McCabe SK, et al. (2014) A novel model for cyanobacteria blooms formation: The critical role of anoxia and ferrous iron. Freshwater Biology 59: 1323-1340.

35. Rastogi RP, Madamwar D, Incharoensakdi A (2015) Bloom dynamics of cyanobacteria and their toxins: Environmental health impacts and mitigation strategies. Frontiers in Microbiology 6: 1254.

36. Sutherland WJ, Bailey MJ, Bainbridge IP, Brereton T, Dick JTA, et al. (2010) Future novel threats and opportunities facing UK biodiversity identified by horizon scanning. Journal of Applied Ecology 45: 821-833.

37. Depledge MH, Galgani F, Panti C, Caliani I, Casini S, et al. (2013) Plastic litter in the sea. Mar Environ Res 92: 279-281.

38. Wright SL, Thompson RC, Galloway TS (2013) The physical impacts of micro plastics on marine organisms: A review. Environ Pollut 178: 483-492.

39. Rochman CM (2013) Plastics and priority pollutants: Multiple stressors in aquatic habitats. Environ Sci Technol 47: 2439-2440.

40. Wagner M, Scherer C, AlvarezMu˜noz D, Brennholt N, Bourrain X, et al. (2014) Microplastics in freshwater ecosystems: What we know and what we need to know. Environmental Sciences Europe 26: 12.

41. Darwall, WR, Freyhof J (2015) Lost fishes who is counting? The extent of the threat to freshwater fish biodiversity. Conservation of Freshwater Fishes 1-35.

42. Scheffers BR, DeMeester L, BridgeTC, Hoffmann AA, Pandolfi JM, et al. (2016) The broad footprint of climate change from genes to biomes to people. Science 354: 7671.

43. Ficke AD, Myrick CA, Hansen LJ (2007) Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries 17: 581-613.

44. Parmesan C (2006) Ecological and evolutionary responses to recent climate change. Annual Review of Ecology Evolution and Systematics 37: 637-669.

45. Hermoso V (2017) Freshwater ecosystems could become the biggest losers of the Paris agreement. Global Change Biology 23: 3433-3436.

46. Bassar RD, Letcher BH, Nislow KH, Whiteley AR (2016) Changes in seasonal climate outpaces compensatory density-dependence in eastern brook trout. Global Change Biology 22: 577-593.

47. Pittock J, Hansen LJ, Abell R (2008) Running dry: Freshwater biodiversity protected areas and climate change Biodiversity 9: 30-38.

48. Rahel FJ, Olden JD (2008) Assessing the effects of climate change on aquatic invasive species. Conservation Biology 22: 521-533.

49. Walters LJ, Brown KR, Stam WT, Olsen JL (2006) E-commerce and Caulerpa: Unregulated dispersal of invasive species. Frontiers in Ecology and the the Environment 4: 75-79.

50. Kay SH, Hoyle ST (2001) Mail order the internet and invasive aquatic weeds. Journal of Aquatic Plant Management 39: 88-91.

51. Humair F, Humair L, Kuhn F, Kueffer C (2015) E-commerce trade in invasive plants. Conservation Biology 29: 1658-1665.

52. Sonricker Hansen AL, Annie Li, Joly D, Mekaru S, Brownstein JS (2012) Digital surveillance: A novel approach to monitoring the illegal wildlife trade. PloS One 7: e51156.

53. Di Minin E, Fink C , Tenkanen H, Hiippala T (2018) Machine learning for tracking illegal wildlife trade on social media. Nature Ecology and Evolution 2: 406-407.

54. Freeman MC, Pringle CM, Jackson CR (2007) Hydrologic connectivity and the contribution of stream headwaters to ecological integrity at regional scales. J of the American Water Resources Association 43: 5-14.

55. Juracek KE (2015) The aging of America's reservoirs: In-reservoir and downstream physical changes and habitat implications. J of the American Water Resources Association 51: 168-184.

56. Pompeu PS, Agostinho AA, Pelicice FM (2012) Existing and future challenges: The concept of successful fish passage in South America.River Research and Applications 28: 504-512.

57. Chapman JM, Proulx CL, Veilleux MAN, Levert C, Bliss S, et al. (2014) Clear as mud: A meta-analysis on the effects of sedimentation on freshwater fish and the effectiveness of sediment-control measures. Water Research 56: 190-202.

58. Holeton C, Chambers PA, Grace L (2011) Wastewater release and its impacts on Canadian waters. Canadian J of Fisheries and Aquatic Sciences 68: 1836-1859.

59. Bácsi I, B-Béres V, Kókai Z, Gonda S, Novák Z, et al. (2016) Effects of non-steroidal anti-inflammatory drugs on cyanobacteria and algae in laboratory strains and natural algal assemblages. Environmental Pollution 212: 508-518.

60. Richmond EK, Rosi-Marshall EJ, Lee SS, Thompson RM, Grace MR (2016) Antidepressants in stream ecosystems: influence of selective serotonin reuptake inhibitors (SSRIs) on algal production and insect emergence. Fresh water Science 35: 845-855.

61. Bean TG, Bergstrom E, Thomas-Oates J, Wolff A, Bartl P, et al. (2016) Evaluation of a novel approach for reducing emissions of pharmaceuticals to the environment. Environmental Management 58: 707-720.

62. Stone V, Nowack B, Baun A, Vanden Brink N, von der Kammer F, et al. (2010) Nanomaterials for environmental studies: Classification, reference material issues, and strategies for physicochemical characterization.Science of the Total Environment 408: 1745-1754.

63. Lee J, Mahendra S, Alvarez PJJ (2010) Nanomaterials in the construction industry: A review of their applications and environmental health and safety considerations. ACS Nano 4: 3580-3590.

64. Tong S, Fine EJ, Lin Y, Cradick TJ, Bao G (2014) Nanomedicine: Tiny particles and machines give huge gains.Annals of Biomedical Engineering 42: 243-259.

65. Berkner S, Schwirn K, Voelker D (2016) Nanopharmaceuticals: Tiny challenges for the environmental risk assessment of pharmaceuticals. Environmental Toxicology and Chemistry 35: 780-787.

66. Wang P, Lombi E, Zhao FJ, Kopittke PM (2016) Nanotechnology: A new opportunity in plant sciences.Trends in Plant Science 21: 699-712.

67. Von der Kammer F, Ferguson PL, Holden PA, Masion A, Rogers KR (2012) Analysis of engineered nanomaterials in complex matrices (environment and biota): General considerations and conceptual case studies. Environmental Toxicology and Chemistry 31: 32-49.

68. Folt CL, Chen CY, Moore MV, Burnaford J (1999) Synergism and antagonism among multiple stressors.Limnology and Oceanography 44: 864-877.

69. Jackson M, Loewen CJG, Vinebrooke RD Chimimba CT (2016) Net effects of multiple stressors in freshwater ecosystems: A meta-analysis. global change Biology 22: 180-189.

70. https://www.ctc-n.org/system/files/dossier/3b/combinepdf.pdf

71. Poornima D, Aruselvi G (2020) Implementation of precision soil and water conservation agriculture (PSWCA) through machine learning, cloud-enabled IoT, Integration and wireless sensor Network, European Journal of Mol. And Clinical Med 7: 5426-5446.

72. UNEP (2006) Water quality for ecosystem and human health. United Nations Environment Programme Global Environment Monitoring System (GEMS)/Water Programme.