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Opinion

Catchment Management of Headwater Lakes

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Abstract

The aim of this paper is to discuss the catchment processes that feed the lakes and propose environmentally sound management of catchment-lake interactions in distant mountain headwater regions to support the UN targets on sustainable development. About one third of the global lakes are in high mountains and most are oligotrophic, which means that external and internal lake processes can change rapidly by perturbation in climate and anthropogenic activities. Their functions are still not well understood; research there needs to be reoriented to focus on the tolerances, catchment-lake interactions, and the downstream impacts. The acceptable environmental management also demands a change in social attitudes. This includes a shift in emphasis from granting primacy to short-term economic gains and away from belief in the, still current myth, that it is desirable for technology, routinely, to replace the functions of nature.

Key Words: Headwaters; distant lakes; nonpoint pollution; global climate change; sustainability; catchment management.

Introduction

The upper catchments of river basins (headwaters) are often the most environmentally sensitive parts of the earth [1]. These regions consist of great reserves of natural resources which need to be exploited carefully and managed sustainably. Particularly, they are the ultimate source of terrestrial freshwater: mountain watersheds are considered as the water towers for humanity [2]; wide range of ecological and human crises result just from incorrect management of headwater resources.

Important components of headwaters are distant high-altitude lakes, both natural lakes with rich biodiversity and man-made multipurpose reservoirs (for drinking water supply, irrigation, electricity, recreation etc.). Their functions and environmental processes are still not well understood [3]. About one third of the global lakes are in high mountains [4] and most are oligotrophic, which means that external and internal lake processes can change rapidly by perturbation in climate and anthropogenic activities [5]. The changes to internal processes are primarily due to temperature variation which changes the length of ice cover that alters lake radiation processes, methane emissions and evaporation [6]. The external factors that impact lakes are primarily land use activities and climate change. Because mountain lakes are in fragile environments, the temperature regime, chemical and nutrient cycles and the ecosystem of aquatic organisms can change rapidly [7], [8]. As a result, mountain lakes have been identified as some of the best indicators of climate and environmental change [9]. Although mountain lakes are highly variable, the average surface temperatures of the lakes have increase more rapidly than the global land temperatures [10]. The changes in internal processes

have been given considerable attention, but changing conditions in the catchment that feeds the lakes need more attention. Distant from direct man's interventions and sources of point pollution the headwater lakes are affected mainly by the land use changes in their catchments, aerial pollution (deposition of elements from the atmosphere) and the global climate change. They tend to be on the front line of ecological change and pose the greatest challenges for those engaged with land management, policy, and planning. The aim of this paper is to discuss the catchment processes that feed the lakes and propose environmentally sound management of catchment-lake interactions in distant mountain headwater regions to support the UN targets on sustainable development [11].

Discussion

Arial pollution and global climate change

Distant headwater areas are particularly affected by large scale air pollution (emissions of SO2, NOx, NH4) and atmospheric acid deposition increasing from the industrial revolution and culminated in the late 1980s. The atmospheric load of sulphur and nitrogen can be modified by both control of atmospheric emissions and the vegetative canopy. The long-term environmental monitoring in headwaters confirmed the effects of the canopy reduction and shift from coniferous to deciduous species on the drop in the acid deposition and a recovery of surface waters from acidification, [12]. Deposition of dust origination from distant regions contribute to nutrient enrichment (phosphorus) which is enhanced by increasing windstorms [5]. Climatic change has a magnifying impact on the lake stratification and biochemistry, and stream hydrology resulting in more extensive extreme events (floods and draughts] affecting the downstream lake management [13]. Due to higher temperatures and more variable precipitation, the stream hydrology is changing in different ways depending on the prevailing runoff regime (glacier, snow or rain dominated). According to recent observations and outputs from climate models, more intensive warming and consequent climate changes occur just in headwater areas. These changes cause significant shifts in the climax zonation.

Headwater wetlands

In headwater catchments, there is significant extend of wetlands of special environmental value [14]. For many years, they have been granted little value, recognised mainly as areas with a potential for land use conversion (reclaimed through drainage, forestation and agricultural development]. More recently, it has been recognised that headwater wetlands can provide many valuable environmental services. But, the existing wetland research has focused predominantly on their internal attributes while their role in wider watershed contexts is at the margin of interest. This problem, the undervaluing of headwater wetlands, was identified, originally, by delegates at the International Conference on Sustainable Management of Headwater Resources, (Nairobi, 2002) and the major output was declared by the Nairobi Declaration for the International Year of Freshwaters 2003, ratified by five United Nations agencies [8].

Ecosystem services

Generally, the concept of environmental services is based on the link between flows of values to human societies as the result of the state and quantity of natural capital. In headwater landscapes, nature provides a wide range of essential environmental services that have been under-appreciated and the value for such services has for a long time eluded satisfactory economic evaluations [15]. Headwater areas worldwide are mostly forested, thus forestry practices are among the most important factors of their environmental benefits. The required concept of multi resource forestry and 'Protective forests' concentrates on maintaining forests as the biophysical systems and the open collaborative watershed management as well as the social and environmental impact assessment. But this concept has been now deteriorated by the global climate change. The more rapid warming in the mountains is leading to a upwards movement of the vegetation, which is resulting in zonal changes in vegetation patterns and upwards forest expansion. How this impacts the hydrology of the catchment has not been given much attention. Using the projections of many different global models there is good agreement that the temperatures are increasing rapidly, and, there is also considerable evidence that headwaters are warming up faster than lowland areas [16].

Land use policy

Particular attention has been paid to mountain environments by religions and pilgrimage traditions [1]: mountains are considered a place of guardianship, recovery, and expectancy in biblical poems throughout Jewish and Christian history, sacred places in Japanese religion beliefs, or pegs stabilizing the earth in the Quran. In modern societies, with the decline of traditional beliefs the role of legislative restrictions increases. Anyway, designing effective land use policies for headwater areas is challenged by uncertainties related to changes in environmental, political and socio-economic circumstances, and by increasing extreme climatic events. The existing land use policy in protected headwater catchments in the Czech Republic (Water Act 138/1973) were found to be ineffective [12] in those circumstances. At the catchment scale, the proposed scenarios of structured forestry zones. expanded riparian buffers zone, steep slope protection fog drip areas and wetland expansion can be employed. Effective ecosystem services should reflect also the changing human society: social and political stress can lead to conflicts and land abandonment deteriorating the projected services of headwater landscapes. Distant mountain lakes are vulnerable ecosystems and their functioning is still not well understood. Multidisciplinary studies on headwater catchment-lake interactions, their individual history and the stressors they face, need to be developed for effective environmental services.

Conclusion

A new and comprehensive inventory of headwater watersheds is urgently required. Research there needs to be reoriented to focus on the tolerances, exchanges, checks and balances within headwater landscapes, catchment-lake interactions, and the downstream

impacts. There is a need for better data, especially from longer-term environmental monitoring, for better management models and for a greater sharing and utilisation of existing information. The effective management of headwater catchments requires new policy frameworks, changes in land husbandry, more sensitive technological intervention and the full integration of headwater ecosystems into planning. It also needs better systems for community education and more effective participatory processes. The aim of Headwater Control is to define and implement appropriate self-sustainable management strategies that meet the needs of the headwater habitat, including its human inhabitants, as well as those of habitats and communities downstream. For the future, it is hoped that more may be done to develop the role that could and should be played by environmental education for sustainable development because, over recent meetings, it has become obvious that improved watershed management, like all environmental management demands a change in social attitudes. This includes a shift in emphasis from granting primacy to short-term economic gains and away from belief in the, still current myth, that it is desirable for technology, routinely, to replace the functions of nature.

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References

1. Křeček J and Haigh M (2019) Land use policy in headwater catchments. Land Use Policy 80: 410-414.
2. Messerli B, Viviroli D, Weingartner R (2004) Mountains of the world: vulnerable water towers for the 21st century. Ambio 13: 29–34.
3. Machate O, Schmeller DS, Schulze T, Schulze T, Brack W (2023) Review: mountain lakes as freshwater resources at risk from chemical pollution. Environmental Sciences Europe 35(1): 3.
4. Loria KAD, McKnight DM, Ragar DM, Johnson P (2020) The life aquatic in high relief: shifts in the physical and biological characteristics of alpine lakes along an elevation gradient in the Rocky Mountains, USA. Aquat. Sci. 82: 11.
5. Oleksy IA, Baron JS, Beck WS (2021) Nutrients and warming alter mountain lake benthic algal structure and function. Freshwater Sciences.
6. Hampton S, Baron JS, Ladwig R; McClure R, Meyer MF, et al. (2023) Warming-induced changes in benthic redox as a potential driver of increasing filamentous algal blooms in high-elevation lakes. Limnology and Oceanography Letters 9: 1-6.
7. Szabó Z, Buczk K, Aritina H, Róbert-Csaba Beg, Daniel Veres, et al. (2020) Ecosystem shift of a mountain lake under climate and human pressure: A move out from the safe operating space. Sci. Total Environ743: 140584.
8. Oleksy IA, Baron JS, Leavitt PR, Spaulding SA (2020) Nutrients and warming interact to force mountain lakes into unprecedented ecological states. Proc. Biol. Sci. 287: 20200304.
9. Moser K A, Baron JS, Brahney J, Oleksy IA, Christianson K R et al. (2019) Mountain lakes: eyes on global environmental change. Glob. Planet. Change 178: 77–95.
10. O'Reilly, C Sharma S, Gray D, Klaus D, Joehnk, Kulli Kangur, et al. (2015) Rapid and highly variable warming of lake surface water around the globe. Geophysical Research Letters. 42(24): 10,773-10,781.
11. United Nations (2024) Progress towards the sustainable development goals. Report of the Secretary-General, 79th Session, Economic and Social Council, UN, New York, 26 pp.
12. Křeček J, Palán L, Stuchlík E (2019) Impacts of land use policy on the recovery of mountain catchments from acidification. Land Use Policy 80: 439-448.
13. Schreier H (2017) Maintaining environmental services in mountain watersheds. In: Křeček J, Haigh M, Hofer T, Kubin E, Promper K (Editors), Ecosystem services in headwater catchments, Springer, Cham, Switzerland, pp. 139-150.
14. Křeček J, Haigh M (2006) Environmental role of wetlands in headwaters. Springer, Dordrecht, 354 pp.
15. United Nations University (2002) Nairobi „headwater" declaration for the International Year of Freshwater 2003. United Nations University, Tokyo, Japan, 6 pp.
16. Pepin NC, Arnone E, Gobiet, A. Haslinger KA, Kotlarski S, et al. (2022) Climate changes and their elevational patterns in the mountains of the world. Review of Geophysics, 60(1).