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Managing reservoir fisheries: a critical look at reservoir physical environment

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Abstract This short note follows a discussion on a study that assessed reservoir fisheries and ecosystem-based management approaches in Ghana. The main objectives of the study were to develop an understanding of how differences in reservoir morphometry and physicochemical characteristics influence ecosystem structures and fisheries productivity. This involved reviewing and updating empirical models for reservoir harvest estimations, relating morphometric characteristics of the reservoirs to fish production, assessing the exploitation levels and stock status of the reservoirs' target species and providing a holistic description of the reservoirs' biological interactions through a food web modelling approach. To manage reservoirs and associated riverine environments for the benefit of fish and fisheries, reservoirs' status and contribution to capture fisheries production have to be evaluated and addressed. Furthermore, the technical criteria and measures germane to assessment frameworks must be improved. Protecting and enhancing the physical environment of reservoirs for fish production requires considerations of ecosystem perspectives, optimal morphometric characteristics, duration of reservoir filling and development and prevention of critical nutrient enrichment. For enhancing Ghana's fish production, development strategies should focus on fisheries and aquaculture production in rivers, floodplains, lakes, reservoirs, and brackish water systems. Research, policy, and capacity-building issues related to developing these production systems must be addressed adequately. Moreover, to fully exploit their potential, the management requirements of the individual reservoir systems need to be assessed and appropriate regimes implemented with stakeholders.

Keywords: morphometry, physicochemical characteristics, biological interactions, fish production, nutrient enrichment

1. Introduction

Globally, inland fisheries management (including those that operate in reservoirs) is hindered by a lack of scientific understanding of how human activities affect the production potential of rivers and lakes (Cowx et al 2010). Capture fisheries have been heavily exploited worldwide in the past three decades to the extent that fisheries production has stagnated and is likely to dip due to pressures from overfishing, habitat degradation, and pollution, all driven by population increases (Allan et al 2005; Delgado 2003). According to Allan et al (2005), owing to an incomplete understanding of how inland waters function, policymakers, and managers often fail to intervene when fisheries are in decline until the fishery resources have virtually collapsed. Incorporating fisheries into ecosystem approaches for the management of inland waters requires evaluating fisheries exploitation potential and to examine feedback between fisheries, ecosystem productivity and aquatic biodiversity (Beard et al 2011). Findings by (Abobi 2020) and (Abobi et al 2021) suggest reservoirs that are exposed to human activities should be adequately assessed and ecosystem-based management measures developed to sustain the contribution of reservoir fisheries to nutrition and food security and to livelihoods. Indeed, these findings require a critical assessment of approaches to protect and enhance the physical environment of reservoirs for fish production, which is the focus of this short communication.

2. Discussion: enhancing reservoir physical environment, key points for consideration

Reservoirs are rarely constructed solely for fishing. However, as a secondary purpose, fisheries augment the benefits derived from these artificial systems. The factors discussed in the ensuing four paragraphs should be considered in creating an "optimal" reservoir for fishing.

First, the desired fishery should be developed from an ecosystem perspective-including the introduction of commercial species that are adequate in terms of fish production characteristics and ecosystem demands. According to (Cowan Jr et al 2012), the ecosystem approach to fishery has been promoted as one way forward for sustainable management of fisheries resources since it more holistically addresses complex links across human and natural systems, finds conflicts between

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competing ecosystem services, and also directly considers direct and indirect impacts of fishing operations on aquatic ecosystems. Similarly, Garcia and Cochrane (2005) highlight the importance of biotic interactions of target species, other species, living habitats, predators, and prey in a conventional fishery management approach. In Africa, the main goal of fish introductions in reservoirs is to sustain or increase yields from wild fisheries. Several studies indicate increases in yield following fish introductions in reservoirs (Aloo et al 2017; Fernando and Holčík 1982; Fernando and Holčík 1991; Ogutu-Ohwayo and Hecky 1991; Petr and Mitrofanov 1998). However, Fernando and Holčík (1991) stress the need to exercise caution in any fish introduction campaign. The impacts of predatory species have been noted. Piscivores have often reduced or even eliminated many resident species in areas where they have been introduced (Ogutu-Ohwayo and Hecky 1991). Also, it has been noted that fish introductions can lead to changes in aquatic ecosystem structure and function. Compared with the direct effects of predation or competition, the effects of ecosystem alterations may be more subtle but may have consequences for the entire fish community and total fish productivity rather than just for the immediate prey or competitor species. Therefore, it is crucial to introduce fish that are adequate in terms of fish production characteristics and ecosystem demands.

Secondly, reservoirs should be constructed with an appropriate size and depth that allows for adequate water spread and habitat diversity for the aquatic fauna and flora. They should be large enough to withstand intense periods of water loss due to droughts. Considering the projected severity of climate change impacts in the region and its associated high evaporation rate (1.5-2 m) and prolonged periods of droughts, a reservoir intended for both irrigation agriculture and fisheries should thus have a surface area of not less than 2 km^2 and a mean depth of 4m (Abobi 2020). It has been noted that there is a positive association between invertivorous fish and reservoir size (Dos Santos et al 2017). While work done by Abobi et al (2021) indicates that fisheries productivity is inversely related to reservoir size, it was reported that the use of small reservoirs in populated semi-arid environments for both irrigational farming and fisheries production is unsustainable due to problems associated with seasonal water loss, siltation and aquatic habitat degradation. In tropical regions, precipitation and filling of reservoirs are the most critical stages of reservoir fisheries production and thus making reservoir surface area and depth important factors to consider in creating an optimal reservoir for fisheries production. A study by Schneider et al (2015) compared the macrophyte species richness, composition, and vegetation height in water bodies and assessed the most important abiotic explanatory variables (morphometric, physical, and chemical) associated with these assemblage attributes. Species richness and macrophyte assemblage composition were associated with depth, among other factors. Again, these findings demonstrate the importance of reservoir morphometric characteristics to the functional composition and diversity of aquatic flora, which are responsible for primary production in aquatic ecosystems.

Third, the time for maximum filling and system development after construction needs to be taken into account, which very much relates to the size of the reservoir. During the reservoir filling stage, submerged vegetation needs to decompose and soils and sediments need to settle. This is crucial as it has been noted that it may take decades or even centuries for most of the organic matter to decompose (McCully 1996). A thorough clearing of vegetation in the submergence zone is needed before a reservoir is filled. This would allow the acceleration of the reservoir development.

Fourthly, critical nutrient enrichment should be prevented. Under eutrophication conditions, tropical reservoirs may be colonised by aquatic weeds such as water hyacinth (*Eichhornia crasspipes*), which can cover water bodies entirely. While these aquatic macrophytes can function as shelter and substrate for young fish (Petrere 1996), excess growth and thick layers of aquatic plants may affect water quality. They can negatively impact the life of fish species and other aquatic organisms and fishing activity (Figure 1). Regulating agriculture and livestock activities within the reservoirs' catchment area will be needed to reduce the introduction of excessive organic matter input into the reservoirs (Abobi and Wolff 2020). In principle, adequate light penetration and nutrient cycling in the reservoir will create optimal conditions for enhanced production (Figure 1).

The Figure 1 provided in this short communication illustrates the benefits and negative environmental consequences of dam construction in tropical regions, which is useful in placing the adaptation and development of fish communities in a relationship with other environmental consequences of impounding the rivers of Africa. The figure was first developed following a project that assessed the environmental impact of a large tropical reservoir and provided guidelines for policy and planning, based on a case study of Lake Volta, Ghana, in 1973 and 1974 (Freeman 1974). The Figure demonstrates that the creation of a reservoir can lead to (i) inundation of agricultural lands, settlements, cultural and archaeological sites, and forests, which can negatively impact fishing as the forest when not adequately removed are left standing in the reservoir and obstructing fishing activities; (ii) the development of new aquatic ecosystem which subsequently creates new spawning environment, new temperature regime and new primary production which determine fish adaptation and fish production rates, phytoplankton and zooplankton production. Reduction in light and phytoplankton production results in reduced primary production and consequently a decline in total fish production and fish catch; and (iii) the creation of disease vector habitats such as open water with water weeds, reservoir edge, quiet water and spillway. These habitats lead to the breeding and prevalence of tropical diseases such as malaria, schistosomiasis, trypanosomiasis, filariasis, onchocerciasis, and other borne pathogens, which have an aquatic snail or fish as host. Management approaches to control water weeds and tropical diseases entail additional costs as well as benefits.

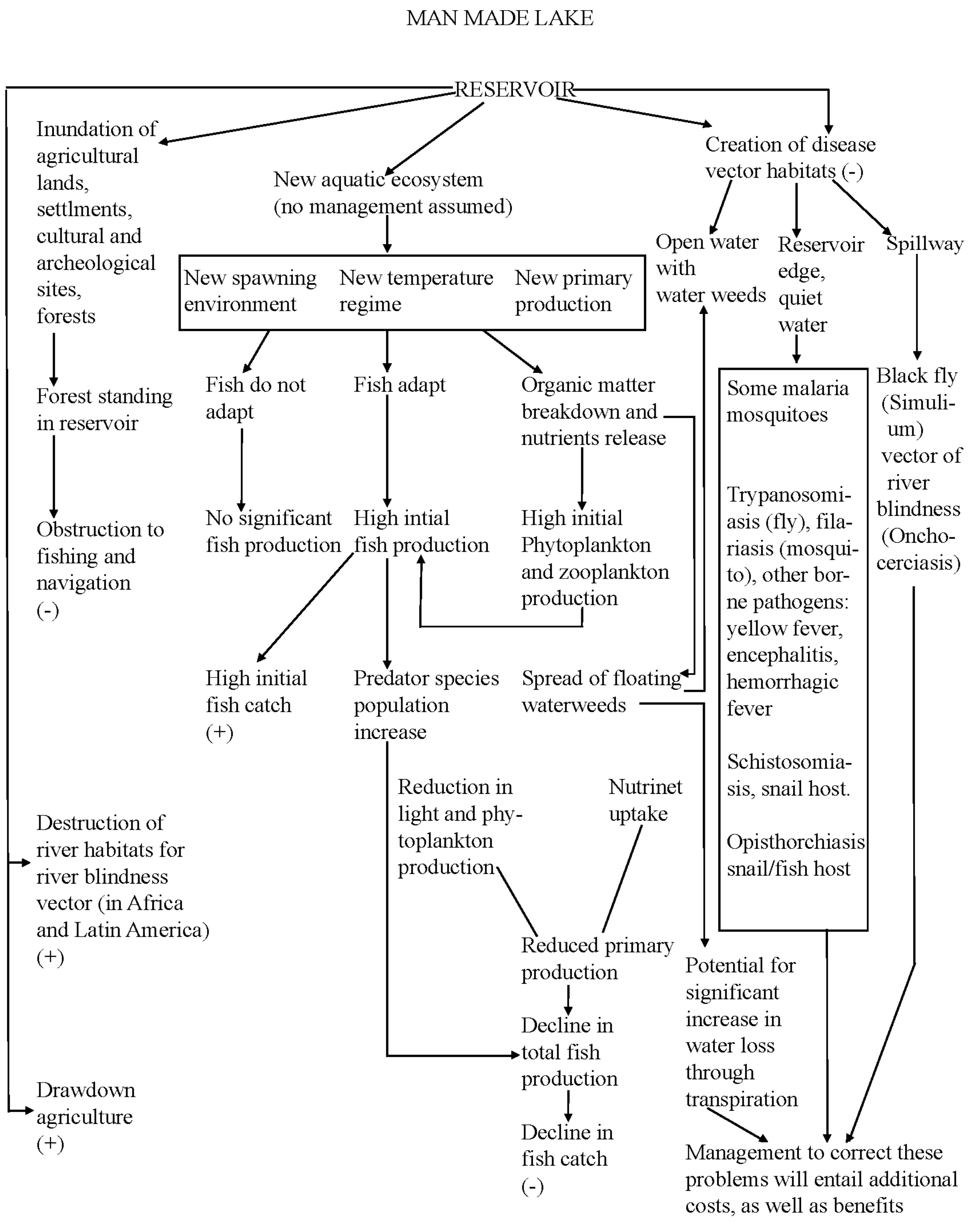

Figure 1 A simplified diagram showing the environmental consequences [Benefits (+) and Costs (-)] of a tropical river impoundment. Redrawn and modified from Freeman (1974) by Petr (1978).

3. Conclusions

Successful management of reservoir systems for fish production requires successful management of agriculture activities in reservoir catchment areas to create a win-win situation for fisheries and agriculture production. As shown in the Figure, the benefits and negative consequences of river impoundment are associated with the development of fish communities in reservoirs. The drawdown of a reservoir's water benefits agricultural production while reducing the size of the aquatic habitat available for fish production. Siltation is the most critical factor that affects reservoir shape, size, and turbidity.

It results from the excessive transport of sediments and silts from reservoirs' catchment areas, and this process has reduced the surface areas of the reservoirs in Northern Ghana (Abobi 2020). Controlling the submerged aquatic macrophytes of reservoirs will enhance the utilisation of primary production and improve the reservoirs' water quality and fishing activity.

Conflict of Interest

The authors declare no conflicts of interest.

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References

Abobi SM (2020) Fisheries Assessment and Trophic Modelling of Tono, Bontanga and Golinga Reservoirs, Ghana. PhD Dissertation, Universität Bremen, Germany.

Abobi SM, Kluger LC, Wolff M (2021) Comparative assessment of food web structure and fisheries productivity of three reservoirs in Ghana Fisheries Management & Ecology 28:573-591

Abobi SM, Wolff M (2020) West African reservoirs and their fisheries: An assessment of harvest potential Ecohydrology & Hydrobiology 20:183-195 DOI: 10.1016/j.ecohyd.2019.11.004

Allan JD, Abell R, Hogan Z, Revenga C, Taylor BW, Welcomme RL, Winemiller K (2005) Overfishing of inland waters BioScience 55:1041-1051

Aloo PA, Njiru J, Balirwa J, Nyamweya C (2017) Impacts of Nile Perch, Lates niloticus, introduction on the ecology, economy and conservation of Lake Victoria, East Africa Lakes & Reservoirs: Research & Management 22:320-333.

Beard TD, Arlinghaus R, Cooke SJ, McIntyre PB, De Silva S, Bartley D, Cowx IG (2011) Ecosystem approach to inland fisheries: research needs and implementation strategies Biology Letters 7:481-483.

Cowan Jr JH, Rice JC, Walters CJ, Hilborn R, Essington TE, Day Jr JW, Boswell KM (2012) Challenges for implementing an ecosystem approach to fisheries management Marine and Coastal Fisheries 4:496-510.

Cowx I, Arlinghaus R, Cooke S (2010) Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters Journal of Fish Biology 76:2194-2215.

Delgado CL (2003) Fish to 2020: Supply and demand in changing global markets vol 62. WorldFish..

Dos Santos NCL et al (2017) Environmental filters predict the trait composition of fish communities in reservoir cascades Hydrobiologia 802:245-253

Fernando C, Holčík J (1982) The nature of fish communities: a factor influencing the fishery potential and yields of tropical lakes and reservoirs Hydrobiologia 97:127-140.

Fernando C, Holčík J (1991) Fish in reservoirs International Review of Hydrobiology 76:149-167.

Freeman PH (1974) The Environmental Impact of a Large Tropical Reservoir: Guidelines for Policy and Planning. Based Upon a Case Study of Lake Volta, Ghana, in 1973 and 1974. Washington DC., Office of International and Environmental Programmes, Smithsonian Institute.

Garcia SM, Cochrane KL (2005) Ecosystem approach to fisheries: a review of implementation guidelines ICES Journal of Marine Science 62:311-318.

McCully P (1996) Silenced rivers: The ecology and politics of large dams. Zed Books.

Ogutu-Ohwayo R, Hecky R (1991) Fish introductions in Africa and some of their implications Canadian Journal of Fisheries and Aquatic Sciences 48:8-12.

Petr T (1978) Tropical Man-made Lakes. Their ecological impact. Archiv fur Hydrobiologie 81:368-385.

Petr T, Mitrofanov VP (1998) The impact on fish stocks of river regulation in Central Asia and Kazakhstan Lakes & Reservoirs: Research & Management 3:143-164.

Petrere M (1996) Fisheries in large tropical reservoirs in South America Lakes & Reservoirs: Research & Management 2:111-133.

Schneider B, Cunha E, Marchese M, Thomaz SM (2015) Explanatory variables associated with diversity and composition of aquatic macrophytes in a large subtropical river floodplain Aquatic Botany 121:67-75.