Resilient Lagoons? Climate change, sustainability and adaptation

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Introduction

Lagoons are found at low-lying coastlines around the globe (Fig. one) and their associated wetlands are important, dynamic coastal environments. Ensuring the sustainability of the world's lagoons is vital for communities, ecosystems and economies. They support highly productive ecosystems and provide critical ecosystem services, societal benefits and myriad fundamental, valuable resources that are vital for the wellbeing and livelihoods of coastal communities. Yet the sustainability of lagoons and communities who rely on them are under increasing pressure from a complex set of interconnected issues, including climate change, sea-level rise, pollution, poor waste management, population growth and policy approaches favouring top-down governance to the exclusion of local knowledges and priorities (Convention on wetlands 2021). This *Changing World* article summarises the latest research on lagoons through the examples of Muni Lagoon, Ghana and Lagos Lagoon, Nigeria (Fig. one) as well as the interdisciplinary dialogues emerging through the GCRF funded *Resilient Lagoon Network* https://lagoonnetwork.org/ which is seeking to challenge top-down management approaches by prioritising participatory approaches valuing local knowledges and in which coastal communities are central to resilient lagoon governance.

Lagoon processes

Lagoons are shallow coastal lakes found at the nexus of land and sea. Here, biota and water from ocean and rivers mix to create a distinctive coastal environment. Lagoons formed as sea levels rose at the start of the Holocene, transporting sand onshore that was deposited at the mouth of estuaries. The sand formed beach barriers, which impounded estuaries to form lagoons on their landward side (Fig. two). Beach barriers are the key physical feature of a lagoon. They are transient, responding to variations in sea level and coastal sediment budget as well as local weather, oceanic and hydrological conditions (Kjerfe 1994). When a barrier is breached a tidal-inlet forms allowing the mixing of lagoon and ocean waters. Breaching can occur randomly or on a regular cycle aligned to rainfall and storm patterns (Davies-Vollum at al. 2018).

Lagoon case studies from West Africa

The Muni lagoon (Fig. three) is a small, peri-urban lagoon on Ghana's central coastline, adjacent to the town of Winneba (population approximately 60,000). The lagoon is intermittently closed lagoon and fed by rivers whose discharge fluctuates greatly between wet and dry seasons resulting in significant hydrological, physicochemical and ecological variation. At the end of the wet season the lagoon covers approximately 1000 ha but by the end of the dry season it shrinks to about 100 ha with salinity higher than the adjacent ocean. Breaching of the lagoon barrier releases lagoon freshwater to the ocean while allowing ocean water to enter the lagoon. Breaching commonly takes place at the end of the heaviest rainy seasons, when water levels in the lagoon are at maximum. The breach closes during the dry season by deposition of sand transported by longshore ocean currents. Muni lagoon has high habitat diversity and is globally important as a staging post for migrating waterbirds (Ntiamoa-Baidu et al, 2000). Because of this, in 1992 it was

designated as a Ramsar[1] site, a wetland site of international importance. The lagoon and barrier provide a number of socio-economic benefits and resources to the local community including fish, mangroves, salt production and sand for construction.

The Lagos Lagoon is an urban lagoon around which the city of Lagos is built (Fig. four). Lagos is the most populous city in Nigeria, and one of the fastest-growing cities in Africa with estimates between 17.5 and 21 million. The lagoon is part of the most extensive coastal lagoon complex in West Africa that stretches 257 km from Cotonou (Republic of Benin) to the Niger Delta (Nigeria). An inlet connects Lagos lagoon to the sea and enables use of the lagoon as the city's harbour. The open inlet keeps the water brackish in the lagoon's tidal reaches and shallow, inter-connected creeks supply fresh water. The lagoon is bounded by low-lying marshy areas to the north and south that include mangrove swamps. The principal ocean port of Lagos is located at Apapa, which is unarguably the busiest port in Nigeria and possibly one of the busiest in sub-Saharan Africa. The large population of Lagos depend on the lagoon for potable and recreational water, and fish for affordable protein. The lagoon is also a major source of livelihood. There are two communities (Makoko and Ilaje) known to live in stilt settlements built directly on the lagoon.

Challenges facing lagoons

Challenges facing lagoons and the communities who live around them are complex and inter-connected (Fig. five). This is particularly true of lagoons in the global south, as illustrated by the Muni and Lagos lagoons, where adjacent communities rely on them for resources and livelihood.

Climate related challenges

Coastal lagoons are highly vulnerable to sea level rise and climate change because of their low elevation and their dependence on the dynamic coastal physico-chemical regime for their unique habitats. At Muni lagoon, shoreline retreat and erosion have been observed and attributed to sea level rise, and projections of sea level have confirmed the vulnerability and continued loss of the barrier (Davies-Vollum and West 2015). Changes to the timing and extent of the rainy season have been recorded (Koomson et al, 2020), which not only affects lagoon opening but also increases the potential for flooding. Increased storminess and irregularity of the onset of the rainy season negatively impacts when fishing is possible and thus livelihoods (Koomson et al, 2022). At Lagos lagoon, changes in sea level and rainfall patterns have resulted in more frequent flooding of the City resulting in huge economic losses, estimated as $4m annually across Lagos state (Lucas 2021).

Resource management

Communities that live around lagoons are dependent on them for basic resources such as water, food, fuel and construction materials. With growing populations around coastal lagoons comes increasing resource use. As with many coastal towns in Ghana, Winneba's population is growing and the town is encroaching on the shores of Muni lagoon. This has resulted in unmanaged resource use and subsequent depletion. Until the 1990s mangroves proliferated in the lagoon but they

[1] https://www.ramsar.org

are virtually non-existent now due to overharvesting for cooking fuel and smoking fish in preparation for selling. Attempts at re-planting have had limited success and the resource remains depleted. This is particularly problematic as mangroves are a natural protection to coastal erosion. Removal of barrier sand (known in the region as sand winning) to construct new houses around the lagoon has also taken place despite laws to prevent this.

Waste, sanitation and water quality

The water quality of Lagos lagoon has been impacted by urbanization and industrialization. Studies show the pollution level of the lagoon is greatest in the Lagos harbour area, due to port and oil industry activities. Hydrocarbons are a particular problem, especially when they enter the lagoon ecosystem (Doherty et al. 2019) from urban run-off, spillages related to the petroleum industry, outboard motors and waste oil disposal. At Muni lagoon, urban run-off and lack of sanitation (toilets) are the main causes of pollution, which becomes higher when the lagoon is closed and there is no flushing from the ocean (Mitchell et al. 2017). At both Muni and Lagos lagoons, waste management and disposal is very limited and has resulted in dumping of waste in and around the lagoons. The proliferation of plastic waste is particularly problematic.

Policy responses

Policy and frameworks influencing the governance of lagoons and ~~as~~ wetlands exist at a range of scales. At the international scale, the IPCC (Intergovernmental Panel on Climate Change) provides scientific assessment on climate change and its potential risks, ~~possible~~ adaptation and mitigation and is a key source for informing coastal governance and policy. National Adaptation Programmes of Action (NAPAs) ~~- are submitted to the~~are under the auspices of United Nations Framework Convention on Climate Change (UNFCCC); they outline~~, outlining~~ priority adaptations and interventions for climate change. The Ramsar convention on Wetlands ~~goes beyond climate change; it~~ is an intergovernmental treaty that provides a framework for the conservation and sustainable use of wetlands. A Ramsar designation for a specific coastal site provides a structure and resources for its governance. At the regional scale, collaborative initiatives and frameworks have been developed to support coastal management and governance. Of relevance to the Muni and Lagos lagoons discussed are: the West Africa Coastal Areas Resilience Investment Project (WACA ResIP); the Guinea Current Large Marine Ecosystem (GCLME) programme (GCLME 2006); and the West Africa Coastal Areas Management Program (WACA). Despite these international and regional conventions~~, national planning, and regional~~ and initiatives ~~designed to secure the future of lagoons and their associated wetlands,~~ success in securing the future of lagoons and their wetlands has been limited (Global wetland outlook report 2021, Tooth and Van der Waal 2019). These formal, top down approaches have~~,~~ ~~largely~~ proved unsuccessful because of a 'policy gap' ~~: formal, top down approaches~~, a failure ~~fail~~ to connect ~~international, regional and~~ policy to stakeholders in ways that ~~might be~~are successfully enacted at the local level (Davies-Vollum et al. 2021). Key to a more effective method of creating coastal policy is a "bottom up meets top down approach" in which the lived experiences of coastal stakeholders are included in policy development with coastal communities playing a central role in the design, direction and priorities for lagoon governance.

Resilient futures for lagoons?

Coastal lagoons face a multitude of inter-connected challenges (Fig. five), as briefly illustrated through the cases of the Muni and Lagos lagoons. Addressing these challenges

requires multi-faceted approaches that draw on a range of expertise, experiences and knowledges, linking stakeholders, policy makers, practitioners and researchers. The Resilient Lagoon Network[2] is an international interdisciplinary team that aims to facilitate dialogue and knowledge transfer in ways that foreground local communities' knowledge and expertise to inform the ways in which policymakers conceptualise and respond to the challenges facing lagoons. The network is an example of how the "top down meets bottom up approach" to lagoon policy and governance can be facilitated. ~~emphasises participatory approaches with coastal communities playing a central role in the design, direction and priorities for lagoon governance. It acts as~~ existing as ~~a~~ platform to connect stakeholders and share prtactice, provide information and raise awareness of coastal lagoons.

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References

Convention on Wetlands. (2021). Global Wetland Outlook: Special Edition 2021. Gland, Switzerland: Secretariat of the Convention on Wetlands.

Davies-Vollum, K.S. and West, M. (2015**)** Shoreline change and sea level rise at the Muni-Pomadze coastal wetlands (Ramsar site), Ghana, Journal of Coastal Conservation and Management: 19 (4): 515-525. (https://doi.org/10.1007/s11852-015-0403-y

Davies-Vollum, S., Raha, D. and Koomson, D. (2021) *Climate Change Impact and Adaptation: Lagoonal Fishing Communities in West Africa*, in Leal, W.L., Ogugue, N., Ayal, D., Adeleke, L. and da Silva, I. (Eds) African Handbook of Climate Change Adaptation, Cham: Springer, pp.2222-2242

Doherty, V.F., Adeola, A., Aneyo, I, Otitoloju, A.A. (2019). Histopathological Biomarkers of exposure to Monocyclic Aromatic Hydrocarbons in Clarias gariepinus (African Catfish). Journal of Science and Technology. Universiti Tun Hussein Onn Malaysia Publisher's Office. Vol.11.No.134–44.

Kjerfve B (1994) Coastal Lagoons Processes. In: Kjerfve B (Ed), Coastal Lagoon Processes. Elsevier, Amsterdam, pp. 1-8.

Lucas, B. (2021). Urban flood management in Nigeria. K4D Helpdesk Report 948. Brighton, UK. Institute of Development Studies. DOI: 10.19088/K4D.2021.018

Mitchell, S. Boateng, I. Couceiro, F. (2017). Influence of flushing and other characteristics of coastal lagoons using data from Ghana. Ocean & Coastal Management, Vol. 143, DOI: 10.1016/j.ocecoaman.2016.10.002

Ntiamoa-Baidu Y, Nyame SK, Nuoh AA (2000) Trends in the use of a small coastal lagoon by waterbirds: Muni Lagoon (Ghana). Biodivers Conserv 9: 527-539.

Tooth, S. and van der Waal, B. (2019) The 'Global Wetland Outlook' report, *Geography,* 104(3), pp.154-159

Figure captions

Figure one: Map to show the distribution of coastal lagoons that are noted in the academic literature published from 2020 onwards. Lagos and Muni lagoons also shown.

Figure two: Photo of Muni lagoon Ghana illustrating the main physical features of a lagoon

Figure three: Photo of Muni lagoon, Ghana

Figure four: Photo of Lagos lagoon, Ghana

Figure five: The inter-connected challenges facing lagoons in the Global South