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Coastal lagoons of West Africa: a scoping study of environmental status and management challenges

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Abstract

Lagoons are a major coastal environment in West Africa. They provide a plethora of resources, ecosystem services and economic benefits yet a diverse set of inter-connected stressors are a challenge to their sustainability. A scoping study of the published literature pertaining to lagoons within the region was undertaken to reveal the nature of these stressors and identify gaps in knowledge, providing a resource to inform coastal management practices and reveal areas for future study. Thirty-one lagoons were identified from the scoping exercise covering Nigeria, Benin, Togo, Ghana, Cote D'Ivoire, Liberia and Senegal. The DAPSI(W)R(M) framework was used to structure analysis of the literature and surface key environmental themes. Key drivers and activities established are the use of lagoon resources and expansion of lagoon settlements. The resultant identified pressures are waste, overuse of resources, and urban growth as well as climate change. Resultant stage changes are the degradation of water quality and ecosystems with impacts for the health of lagoon organisms and humans. Responses to changes were identified as a combination of punitive legislation, participatory management approaches and solutions focused on ecosystem restoration and engineering of the physical environment. Gaps identified include research on waste and aspects of climate change mitigation and adaptation. Also notable is a lack of multi- and interdisciplinary studies that address the interconnecting stressors experienced at lagoons and studies of multiple lagoons. Studies also tend to be problem-focused with solutions rarely presented, limiting their applicability to inform management practices.

Keywords Lagoon, Coastal, West Africa, Sustainability, Management

1 Introduction

Coastal lagoons exist at the nexus between land and sea. They are highly productive environments that provide a variety of ecosystem services with cultural, economic and social benefits (Rodrigues-Filho et al. 2023). Growing coastal populations have placed increasing pressure on lagoons and their low-lying topography and dynamic nature mean that they are particularly vulnerable to the effects of climate change (Nicholls et al. 2007, Sanchez-Arcilla et al. 2016) and are regarded as "hot spots" of global change (Newton et al. 2014). In the Global South, lagoons support subsistence communities in both rural and urban areas. Such communities tend to be highly reliant on natural resources associated with the lagoon and the ecosystem services it provides. Pressures of growing population, unplanned development, limited infrastructure and conflicting resource use in and around lagoons compound the effects of climate change (Davies-Vollum et al. 2022). Lagoon communities in the Global South have low adaptive capacity to deal with these multiple

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stressors rendering them and the lagoons that sustain them vulnerable and jeopardising their sustainability.

In West Africa coastal lagoons have a wide distribution and are arguably the dominant coastal environment. They are found along the coast of Senegal, Guinea, Sierra Leone, Liberia, Cote D'Ivoire, Ghana, Togo, Benin and Nigeria west of the Niger delta (Fig. 1), a region that is collectively termed the Guinea Current Large Marine Ecosystem (GCLME). This coastal region experiences a tropical climate that is strongly influenced by the seasonal movement of the inter-tropical convergence zone resulting in two rainy seasons. Lagoons have long been a prime location for settlement in the region because of the multiple resources and services they provide. Some of the region's most developed and fastest-growing urban areas are situated around lagoons. More than a third of the population of Ivory Coast live at the coast (World Bank 2019) and Abidjan, the economic hub of the country, is built around the Ébrié Lagoon with 92.8% of industry located there (Coulibay et al. 2018). Ghana's coastal zone is the most densely populated part of the country and approximately 40% of the population lives in its coastal administrative regions with maximum population density at the coast (Ghana Statistical Service 2021). The majority of Benin's population live along the coast in and around the of capital Cotonou, situated on Nokou Lagoon (World Fact Book). Nigeria's largest city, and Africa's fastest growing city, Lagos, sits on the shores of Lagos-Lekki lagoon complex and over half of Senegal's population live at the coast (World Bank 2019).

Lagoons are essential to the West African economy. Coastal lagoon systems in Africa were estimated to provide goods and services of over US$500 billion annually in the late 1990s (Glavovic 2000) and as coastal populations have grown this economic importance has remained. In West Africa, coastal lagoons play a key role in fisheries, contributing to both regional and local economies with small-scale fishing (SSF) the main economic livelihood for communities living around lagoons (Davies-Vollum et al. 2021). Lagoon communities are not only reliant on locally caught fish for their livelihood but also their sustenance with SSF critical to local and regional food security. In addition to fisheries, lagoons provide other essential resources such as water for washing, sand for construction and wood for fuel and housing, which are essential to the livelihood, wellbeing and health of lagoon communities. Lagoons also form natural sheltered coastal areas that have been developed as key

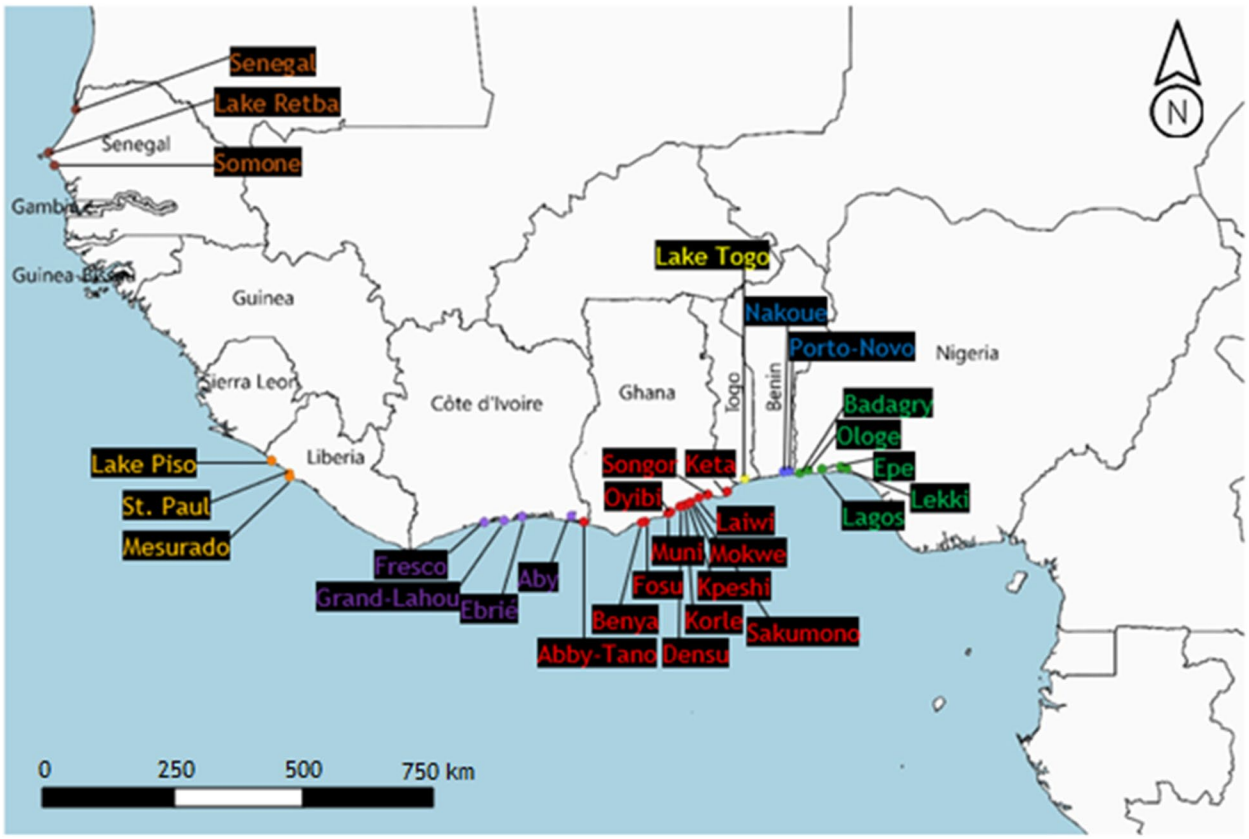

Fig. 1 Map of West African coastline with lagoons included in study shown

ports in the region that enabled the development of trade links. These ports have experienced much recent development supported by foreign direct investment (Konsantius and Woxenius 2022). Abdijan (Ivory Coast) built around Ebrie lagoon is the second largest port in Africa and other substantial lagoon-ports in the region include those at Tema (Ghana), Dakar (Senegal) and Lagos (Nigeria). Population growth has placed increased stress on lagoons and they are heavily impacted by anthropogenic activities and pressures. Lagoons in the region are also highly vulnerable to climate change, in particular sea level rise and changing storm and rainfall patterns, which cause physico-chemical changes, affect natural lagoon cycles and impact biota and ecosystems. The interplay between these inter-connected non-climate and climate stressors increases community and environmental vulnerability and is essential to understand for the effective and sustainable management of these critical coastal environments.

Here we provide results of a scoping study of the literature available on West African lagoons. The study compliments similar review articles of lagoons in Europe (Newton et al. 2014) and North Africa (El Mahrad et al. 2020). The study retrieved and reviewed the available literature on coastal lagoons in West Africa to understand the status of the challenges facing these environments and to identify where there are geographic and content gaps in knowledge. Thus, the study provides a resource that can both inform coastal management practices in the region and help focus areas for the future study of lagoons.

2 Materials and methods

2.1 Study areas

The scoping review focused on coastal lagoons in countries within the Guinea Current Large Marine Ecosystem (GCLME). That is Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Togo, Benin, and Nigeria, which all interface with the Gulf of Guinea and the Atlantic Ocean (Fig. 1). For this study, a lagoon was defined as a shallow coastal waterbody approximately 100 m from the sea, permanently or intermittently linked to the sea and characterised by tidal exchanges and fluxes. This aligns with the United Nations glossary of environmental statistics that defines coastal lagoons as "sea water bodies situated at the coast but separated from the sea by land spits or similar land features…and open to the sea in restricted spaces" (UNSD 2006). The lagoons in the region vary in their size, salinity and the nature of their separation from and connection to the open ocean (Davies-Vollum et al. 2021).

2.2 Literature search and data collection

Sources of information for the review were obtained through a systematic literature search for relevant published and unpublished (grey) literature in web-based databases and search engines. These included Science Direct (Scopus), Web of Knowledge (ISI Web of Science), Google Scholar, and Google. The Joanna-Briggs scoping guidelines were adhered to for the search (Peters et al. 2011). The search string was based on generated keywords (English only) and synonyms for Population (lagoons or coastal lakes), Concept (Ecological state or management challenges), and Context (West Africa: Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Togo, Benin, and Nigeria). The search was limited to the period between 1992 – 2021. After several iterations, the final search string used was as follows:

> ("coastal lagoon*" OR "lagoon*" OR coast* lake* OR estuar*) AND (manage* OR challenge* OR problem* OR "manage* challenge*" OR "manage* problem*" OR "resource-use challenge*" OR "resource-use problem*" OR "govern* challenge*" OR "govern* problem*" OR drive* OR activit* OR pressure* OR change* OR impact* OR respon* OR action*) AND (Nigeria* OR Benin* OR Togo* OR Ghana* OR "Côte d'Ivoire" OR "Ivory Coast" OR Liberia* OR "Sierra Leon*" OR Guinea* OR "Guinea-Bissau" OR Gambia* OR Senegal* OR "West Africa*").

The full search string could not be used in the Google search engines due to search string length limitations and unrecognition of Boolean operators within the Google search engines. Thus, these were used as secondary search platforms for unpublished information on individual lagoons which lacked peer-reviewed literature. After removing duplicates, a total of 1,575 published articles were exported and reviewed at title and abstract level. Articles selected for inclusion had to meet the following criteria: they had to address environmental, economic and/or social issues and were based on studies of any coastal lagoon in any of the West African Countries targeted by the study. The decision as to whether a coastal waterbody met our adopted typology of a lagoon or coastal lake and should or should not be included in the review was discussed and agreed by all authors. In addition, due to language proficiency of the reviewers, only articles that had English full text were included in the full text review. Relevant non-English articles with English abstracts were reviewed at abstract level only. A total of 171 articles met the inclusion criteria and were reviewed at full text.

2.3 Charting and evidence synthesis

The DSPIR framework (Atkins et al. 2011) and subsequent amended DAPSI(W)R(M) framework (Elliot et al. 2017) as used by El Mahrad et al. (2020) in a study of North African lagoons and Newton et al. (2014) in a study of European lagoons, was adopted for the data extraction/charting stage. The framework is a widely adopted problem-structuring approach for analysing, understanding, and managing the causes and consequences of change in socio-ecological systems (Atkins et al. 2011, Gregory et al. 2013, Elliot et al. 2017). It structures environmental management problems as emerging from Driving forces of human needs, resulting in Actions which exert Pressures on natural resources, leading to State changes in the resources' ability to deliver essential ecosystems services, which ultimately Impact human and ecological Wellbeing, and require technical and/or policy Responses/Measures to manage. In the charting process, information on each lagoon within the included literature that was related to each of the keywords in the framework were extracted and tabulated in a spreadsheet. The charting was conducted by one of the authors with supervision and agreement of two other authors. The results and discussions which follow are based on the extracted and tabulated information on each lagoon as agreed by all authors in the scoping exercise.

3 Results

3.1 Lagoons identified

A list of the lagoons and their countries included in the scoping reviews is presented in Table 1. The scoping study identified a total of 31 lagoons from the literature. The majority of lagoons identified as being in scope for the study were located in Ghana (13 lagoons) and Nigeria (5 lagoons). Lagoons were also identified from sources for Senegal (3), Liberia (3), Côte d'Ivoire (4), Togo (1) and Benin (2) that were deemed in scope for the study. Lagoons identified from sources retrieved for Gambia, Guinea-Bissau and Guinea did not meet the lagoon definition adopted in this study and thus were deemed out of scope, no sources met the inclusion criteria for Sierra Leone so it was also deemed out of scope for this study. The components of the DAPSI(W)R(M) framework (Elliot et al. 2017): drivers, actions, pressures, impact and responses provide a useful structure to consider the multi- and inter- disciplinary themes that were highlighted in the scoping study.

Table 1 Coastal lagoons included in the scoping review

Country	Lagoons	Total
Senegal	Somone, Senegal, Retba	3
Liberia	Lake Piso, Mesurado, St. Paul lagoon	3
Côte d'Ivoire	Grand Lahou, Ebrie, Aby, Fresco	4
Ghana	Korle, Muni, Keta, Abby-Tano, Kpeshie, Fosu, Benya, Oyibi, Sakumono, Mokwe, Songor, Densu delta, Laiwi	13
Togo	Lake Togo	1
Benin	Lake Nakoue, Porto-Novo	2
Nigeria	Lagos, Lekki, Epe, Badagry, Ologe	5
Total		**31**

Gambia, Guinea-Bissau, and Guinea did not have lagoons that met the definition adopted for the study. No sources met the inclusion criteria for Sierra Leone

3.2 Drivers and activities

The drivers of activities at lagoons are governed by essential human needs such as food, income, and shelter (Maslow 1943). The associated activities that take place to meet those needs in West African coastal communities are listed in Table 2. They can be broadly divided into two categories, the direct use of lagoon resources and the growth of settlements around lagoons. Activities that are predicated on the use of lagoon resources to provide basic human needs in the region are identified as those related to provision of housing and shelter, fishing, engaging in agriculture and aquaculture, washing, and sand extraction. Activities that are predicated on the expansion of settlements around lagoons include the encroachment of housing onto the lagoon and its shores, development of industry, establishment of transportation infrastructure, opportunities for tourism, and issues of solid waste disposal. Table 2 indicates which of these activities were identified for each country.

3.3 Use of lagoon resources

Fishing is by far the most commonly described activity identified in the scoping study and is noted for all countries. Traditional artisanal fishing practices common in West African include acadja and seine fishing (Davies-Vollum et al. 2021). Acadja fishing takes place in lagoons and involves construction of hatcheries made from local vegetation attached to the lagoon floor (Sitondji et al. 2022). Seine fishing is otherwise known as dragnet fishing and mostly takes place in the nearshore environment on the ocean side of lagoon barriers. In some lagoon communities fishing is supplemented by small scale agriculture such as vegetable farming, where lagoon water may be used for irrigation, and localized pastoralism (Duku et al. 2021, Adams 1993). Housing may refer to communities living on lagoon barriers and shorelines but also those living directly on lagoons. Large stilt communities, where communities have constructed dwellings over the lagoon, are located in Ganvie on Lake Nokue (population of 20,000) and Makoko on the Lagos lagoon complex (estimated population 200,000). Most lagoon communities whether situated on or adjacent to a lagoon rely on

Table 2 Activities by country

	Nigeria	Benin	Togo	Ghana	Côte d'Ivoire	Liberia	Senegal
Housing	X	X					
Fishing	X	X	X	X	X	X	X
Agriculture (includes irrigation)	X	X		X	X		
Mangrove harvesting	X						
Aquaculture	X	X		X	X		X
Laundry/washing	X						
Sand winning	X	X		X		X	
Hunting				X			
Pastoralism				X			
Salt mining				X			X
Industry	X						
Encroachment	X						
Transportation	X	X		X	X	X	
Tourism		X		X	X		X
Solid waste disposal	X						

the lagoon water for laundering and bathing. Sand winning, the excavation of lagoon shore or beach sediment, is a common practice that supplies materials for the construction of local structures including dwellings (Jonah et al. 2017, Awosika 1994).

3.4 Expansion of lagoon settlements

Coastal lagoons in the region have not only been the focus of settlement and urban growth but also industrial development. Industrial activities related to development around lagoons are diverse. Examples include saw milling and an oil terminal at the Lagos-Lekki lagoon complex while the Ebrie lagoon is the location for ship building in Abidjan. Urban lagoons are also often a key resource for transportation. This may include the transportation of people and basic resources, as well as industrial products such as logs for sawmills and oil tankers. Lagoons can provide critical transport links in cities where roads are crowded. Tourism is another key activity at some lagoons. Less urbanised lagoons, such as Muni lagoon in Ghana and Somone lagoon in Senegal have become the sites, or are seen as potential sites, for eco-tourism not least because they are critical sites for migratory wetland birds (Willoughby et al. 2001, Armah 1993). Environmentally based tourism is not the only draw at lagoons, cultural tourism is also prevalent, with the stilt village on lake Nokue being a noteworthy example.

3.5 Pressures

The human activities described have resultant pressures on lagoons, their surrounding environments, habitats and associated communities. The pressures result in negative impacts and harm to lagoons. Pressures detected in the scoping study relate to waste management (water and solids), resource management, urban growth and climate change. Table 3 lists these pressures and the countries for which they have been identified.

3.6 Waste

Poor water quality of lagoons is the most commonly cited pressure and is of concern in all countries in the study. Industrialised areas see contamination of water from a huge variety of effluents including oil spills, industrial effluent, agricultural effluent, sewage and septic tank discharges, and pollutants from solid waste landfills. Solid waste discharges include soil, excreta, sawdust, plastics, micro-plastics, polythene, metal cans, medical waste and car tyres. Storm run-off and sediment load can also pollute lagoon waters. Often the source of waste and contamination in the lagoons is difficult to address because of the diffuse nature of the inputs (Troussellier et al. 2004). In urban lagoons, the nature of wastes and their sources is diverse and endemic. The Senegal estuary and lagoon, receives combined urban waste discharge from Dakar (Diop et al. 2014). The Ebrie lagoon receives untreated urban and industrial wastes derived from Abidjan, home to the majority of industry in Ivory Coast (Scheren et al. 2004). In Lake Togo influxes of contaminants include suspended loads from soil erosion, rainwater runoff, urban and hospital effluents (Gnandi et al. 2011). Lagos lagoon is subjected to all forms of pollution but its location as an oil terminus has resulted in high levels of PAH derived from fossil fuels (Akinsanya et al. 2021). Korle lagoon in Accra has long been identified as one

Table 3 Pressures by country

	Nigeria	Benin	Togo	Ghana	Côte d'Ivoire	Liberia	Senegal
Urbanisation	x	x			x		
Wastewater discharge: urban and industrial	x	x	x	x	x		x
Oil spills	x						
N and P enrichment	x	x			x		
Hypoxia	x						
Wet deposition	x						
Solid waste (includes plastics)	x	x		x			
Agricultural run-off	x			x	x		
Resource management & competition				x			
Overfishing/illegal fishing	x	x	x	x	x		
Mangrove harvesting				x		x	
Deforestation		x					
Dredging			x				
Bush burning				x			
Illegal settlements				x			
Breakdown of traditional management				x			
Limited mixing of ocean and fresh waters				x			
Erosion		x		x			
Sea level rise				x			
Flooding				x			

of the most polluted water bodies on Earth (Owusu Boadi and Kuitunen 2002). Accra's waste Management Department has historically had limited capacity to collect waste so that much is dumped in drains and water bodies; Korle, as the principal outlet for the major drainage channels of city, receives much of this (Owusu Boadi and Kuitunen 2002). Annual flooding events exacerbate the problem at Korle bringing additional contaminates from dump sites including e-waste (Huang et al. 2014). A similar situation has been observed for other urban lagoons in the region. Concentration of heavy metals is cited as a specific pressure at Lagos and Ebrie lagoons and Lake Togo. At Lagos lagoon raised levels of heavy metals have been discovered in fish species (Joloaso et al. 2016), at Ebrie lagoon high concentrations of lead, copper, zinc, cobalt and nickel are reported (Bakary and Marcellin 2015) and at Lake Togo leachates from the numerous waste dumps located along the lagoon shoreline have resulted in high levels of mercury (Gnandi et al. 2011). Where lagoon tributaries cross agricultural land, poor water quality associated with farm run-off containing agricultural waste is a problem. Enrichment of nitrogen and phosphorus, associated with fertilizers and pesticides in run off as well as acadja decomposition, has been detected in in lagoons from Benin and Ivory Coast (Djihouessi et al. 2020; Affian et al. 2009). The use of the pesticide DDT has also resulted in chemical pollution of Lake Nokue (Yehouenou et al. 2013).

3.7 Resource over-consumption

Problems with over-consumption and poor management of lagoon natural resources are mainly reported in relation to overfishing and deforestation. Over-fishing was noted in Nigeria, Benin, Ivory Coast, Togo and Ghana (Stoop et al. 2016; Entsua-Mensah 2006, Lae 1994). It includes the use of illegal fishing gears such as drag nets and small-size mesh nets that allow the capture of smaller and immature fish (Koranteng 1998). Fishing in lagoons is particularly sensitive to over-consumption as the optimum fish size for catch coincides with the preferred size for waterbird consumption creating competition between humans and birds (Gbogbo et al. 2008). Deforestation primarily involves the unregulated harvesting of mangroves and their clearance for urban and agricultural land (UNEP 2007). Mangroves are critically important to lagoon ecosystems and as natural protection to erosion. They have an estimated economic value per km^2 of between US $200,000 – US$900,000 yet their decline is noted across the region (Zanvo et al. 2021, 2007 Bryan et al. 2020, UNEP 2007). They are harvested for firewood for cooking and smoking fish in preparation for market (Willoughby et al. 2001, Darkwa and Smardon 2010) and in some areas for the construction of acadjas (Teka and Vogt 2010).

3.8 Urban growth

Urban growth affects all coastal lagoons in the region and is connected to many of the activities and pressures already discussed. This includes unplanned urban growth and the development of illegal and informal settlements around urban lagoons. The growth of Cotonou and Abomey-Calavi has been directly associated with the degradation of natural habitats around Lake Nokue. The Ebrie lagoon in Abdijan has been the focus for industrialisation in the country. Similarly, Lagos lagoon (Lagos), Senegal lagoon (Dakar) and Korle lagoon (Accra) sit at the centre of sprawling, growing urban and industrial centres.

3.9 Climate change

The pressures resulting from climate change at West African lagoons have not been widely reported. The pressure of sea level rise is noted for lagoons in Ghana (e.g. Davies-Vollum and West 2015) although it affects all the coastline in the region (Nyadzi 2020). Coastal erosion, linked to sea level rise, has been described from Benin and Ghana (World Bank 2019). However, it has also been attributed to sand winning in Ghana (Boateng 2012).

4 State change

State change is the effect that pressures resulting from activities at lagoons have on ecosystem services. The state changes revealed by the scoping study can be broadly categorised as the degradation of water quality and the deterioration of ecosystems. Table 4 lists state changes recorded by country. No state changes were identified in the literature sourced for Liberian lagoons.

4.1 Degradation of water quality

Degradation of lagoon water quality is evident in the reported incidences of generally poor water quality and, more specifically, the incidence of hypoxia, eutrophication, algal blooms, water turbidity and salination as well as contamination by heavy metals (described as a pressure above). Poor water quality has been identified in lagoons from across the region (Scheren et al. 2002). Specific cited examples are the Ebrie lagoon noted as severely polluted in its urban bays around Abidjan (Tuo et al. 2012) the Fosu lagoon (Essel et al. 2019) and Korle lagoon (Owusu Boadi and Kuitunen 2002). Eutrophication has been observed as a problem in multiple lagoons from across the region. It is caused by nutrient loading, mainly from nitrogen and phosphorus, which drives high productivity and a proliferation of vegetation and algae that then release toxic carbon dioxide upon decomposition and can lead to hypoxia and anoxia (dead zones). Eutrophication has been identified in Nigerian and Ghanaian lagoons and harmful algal blooms have been recorded in lagoons in Benin, Nigeria, Ivory Coast and Ghana (Akagha et al. 2020, Djihouessi et al. 2020, Ahoutou et al. 2021, Scheren et al. 2004, Guyonnet et al. 2003). Excess salinity is also an indicator of degradation in water quality. Changes to water salinity are governed by freshwater input and the nature of a lagoon's connection to the ocean. Hypersalinities may be reached during dry seasons when lagoon water levels are low, evaporation high and lagoons disconnected from the ocean (Davies-Vollum et al. 2019). The damming of tributary rivers can also adjust lagoon salinity by restricting input of fresh water to lagoons.

Table 4 State change by country

	Nigeria	Benin	Togo	Ghana	Côte d'Ivoire	Liberia	Senegal
Poor water quality	x	x		x	x		
Hypoxia-anoxia	x			x	x		
Eutrophication	x	x	x	x	x		x
Water turbidity	x	x					
Algal blooms	x	x			x		
Water hyacinth blooms	x			x			
Hypersalinity				x			x
Micro-plastic pollution				x			
Bad odour				x			
Habitat loss and reduced lagoon area	x	x		x			
Low species richness		x	x				
Species shifts		x					
No state changes noted in sources						x	

No state changes noted in the literature for Liberia

4.2 Ecosystems

Ecosystem degradation can be viewed in terms of biodiversity loss and reduced species richness and is associated with poor water quality, presence of invasive species and habitat loss. Degradation of lagoon ecosystems has been specifically described for Nigeria, Ghana, Benin and Togo. Low oxygen levels caused by algal blooms and eutrophication are devastating for lagoon organisms resulting in fish mortality and collapse of ecosystems. Increased salinities also have a profound effect on lagoon ecosystems, altering species diversity (Lae 1994). For example, in the Senegal lagoon, a rapid increase in salinity after the lagoon's tributary river was dammed and the lagoon artificially opened resulted in dramatic changes to the microplankton community (Troussellier et al. 2004). Lagoon opening also results in shifts in species composition. In Benin, widening of the lagoon opening of Lake Nokue and resultant increase in salinities has led to shifts from freshwater to marine species and insectivores to detritivores (Djihouessi et al. 2019). The loss of lagoon habitat has been specifically recorded for Nigeria, Benin and Ghana. Lagoon habitats are diminished by deforestation (noted as mangrove loss in 3.3.2), encroachment of physical shoreline development and the proliferation of certain vegetation into the lagoon. Water hyacinth is a problem invasive species in West African lagoons. A free-floating perennial aquatic plant originating from South America, it out-competes native vegetation and can depress oxygen levels. In Nigeria it blooms extensively at Lagos lagoon (Fajemila et al. 2020) and in Benin can cover large amounts of lake Nokue (Djihouessi et al. 2020). In Ghana water hyacinth invasion has been a described from Tano lagoon where it has resulted in a diverse set of problems from the breeding of mosquitoes to obstructing transportation of children across the lagoon to attend school (Honlah et al. 2019). The area of Fosu lagoon was reduced by 50.2 acres between 1970 – 2017 due to the increased incidence of aquatic vegetation and development at the shoreline (Essel et al. 2019).

5 Impacts

Impacts are the effects that the activities, pressures and state changes have on the condition of lagoon habitats and species as well as the health and wellbeing of humans that use the lagoon (Table 5). Impacts recorded are primarily related to the state of fish health and aspects of human wellbeing. No impacts were noted in literature sourced for lagoons in Liberia and Senegal.

5.1 Fish health

The impacts of pressures and state changes on lagoon fish manifests as a reduction in fish health and diversity together with subsequent losses of income generated through fisheries. Quality of lagoon waters is key to the health of fish populations. Contaminated water, anoxia events and eutrophication result in reduced fish diversity and, in extreme cases, fish mortality. Bioaccumulation of heavy metals and pesticides is a contributing factor in poor fish health and has been recorded in lagoon fishes from across the region (for example Onanuga 2012, Jolaoso et al. 2016). At the Ebrié lagoon, fish kills occur annually in the dry season between late November and January when water quality is at its lowest (Bakary and Marcellin 2015). Reduction in fish catch for small scale fisheries is prevalent across the region, not only related to poor health of fish and overfishing but also be due to disruptions in fishing activity associated with lagoon conditions and weather (Koomson et al. 2020). The reduction

Table 5 Impacts of activities, pressures and state changes on lagoon conditions

	Nigeria	Benin	Togo	Ghana	Côte d'Ivoire	Liberia	Senegal
Fish health/growth	x		x		x		
Contaminated fish	x	x		x			
Antibiotic resistant fish	x						
Reduced fish catch	x	x		x			
Water-borne diseases	x			x	x		
Human health	x	x		x	x		
Unsafe for bathing					x		
Land loss				x			
Flooding/reduced water storage				x			
Economic losses	x		x	x			
Resource conflict		x					
Reduced ecotourism	x			x			
No impacts noted in sources						x	x

No impacts noted in the literature for Liberia and Senegal

in fish catch can drive overfishing in attempts to make up for loss of income. This is seen in Togo, where overfishing has resulted in a drop in lagoon biodiversity and a proliferation of a single fish species *Sarotherodon Melanotheron* (Blackchin tilapia) (Lae 1994) and in Benin where the decrease in commercial fish harvest has resulted in intensification of acadja fisheries to make up for economic losses (Stoop et al 2016).

5.2 Human wellbeing

The negative impacts on human wellbeing from pressures and state changes are diverse and include ingestion of contaminated organisms, incidence of waterborne diseases, resource conflicts, flooding, polluted bathing and laundry water, and economic losses (Table 5). The consumption of fish and molluscs contaminated by bioaccumulation of heavy metals and pesticides is reported from Nigeria, Benin, Ghana and Ivory Coast (Joloaso et al. 2016, Adeola et al. 2018, Adeji and Okocha 2011, Acheampong et al. 2014, Scheren et al. 2002). Antibiotic-resistant bacterial strains are also being passed to humans through fish consumption, as reported for fish caught in Nigerian lagoons (Agwu 2013). Another public health dilemma is the outbreak of waterborne diseases at lagoons such as cholera, typhoid, dysentery, and diarrhoea due to poor sanitation and pollution by faecal coliform (Nwanku 1993, Akpata et al. 1993, Mensah 2019b) and the subsequent unsuitability of such lagoons for bathing and laundering. Flooding associated with waste loading and reduced water holding capacity together with sea level rise and unmanaged urban drainage is also problematic for communities surrounding lagoons. In addition to exacerbating water-related public health issues it results in loss of dwellings and disruption to infrastructure. Keta lagoon in Ghana has been particularly affected by a combination of flooding and erosion resulting in loss of coastal villages (Boateng 2012). As well as the loss of income associated with reduced fish catch described above, the general degradation of lagoon environments also impacts livelihoods by reducing potential for tourism activity. Income loss and competition for resources can cause conflict. This type of conflict is prevalent in communities around lagoons in Benin and Ivory Coast where disputes have occurred over land ownership, fishing practices and resource management (Setondji et al. 2021, Doumbia et al. 1993).

6 Responses

Responses are the measures planned, in progress, and implemented to manage the activities, pressures, state change and impacts as evidenced in the scoping study (Table 6). They include legislation, enactment of solutions, and management practices. There was no reference to responses in the literature sourced for Nigeria, Togo and Liberia.

6.1 Legislation

National legislation relating to lagoons is broadly punitive in scope. Bans related to specific fishing practices, such as acadja and seine, are notable (Setondji et al. 2021). There are examples of bans on activity that have been enacted in reaction to a specific event. In Ghana, a ban on fishing and farming activities around the Butuah lagoon was put in place by the local Metropolitan Assembly in 2012 following a fish kill and subsequent poisoning and hospitalisation of people who ate the dead fish (Odjer-Bio et al. 2015). Other legislation is primarily around prohibiting the harvesting of mangroves, often done in association with reforestation policy to restore mangrove forests (e.g. Lombard et al. 2021). Lagoons are classed as coastal

Table 6 Responses implemented to manage activities, pressures, state changes and impacts

	Nigeria	Benin	Togo	Ghana	Côte d'Ivoire	Liberia	Senegal
Ban fish practices		x		x	x		
Ban farming and hunting practices				x			
Resettlement				x			
Ramsar designation		x					
Participatory resource management				x	x		
Mangrove restoration		x		x			x
Lagoon restoration				x			
Flood prevention/sea defences		x		x			
Managed lagoon opening				x			x
Waste management					x		
Education				x			
No responses noted in sources	x		x			x	

No responses noted in the literature for Nigeria, Togo and Liberia

wetlands and thus eligible for Ramsar designation. The Ramsar Convention of Wetlands is an international, intergovernmental treaty that provides a framework for the conservation and wise use of wetlands and their resource (Ramsar 2023). There are lagoons with Ramsar status in Ghana, Benin, Liberia, Senegal and Ivory Coast although Ramsar designation of these specific lagoons is not necessarily mentioned in the literature accessed in the scoping study. Ramsar status is significant as it can afford additional protective legislation to a lagoon based on the tenet of "wise use" (Ramsar 2023).

6.2 Management

Reference to local management practices at lagoons focuses on participatory management, which involves stakeholders and civil society groups as active participants in all aspects of governance. Examples are recorded from Ivory Coast and Ghana. At the Aby lagoon (Ivory Coast) fisheries co-management has improved the sense of ownership and stewardship of the lagoon (Kponhassia and Konan 1996). In Ghana Community Resource Management Areas (CREMA) have been set up around lagoons (Agyare et al. 2015). These lagoons have a designated buffer zone that is collaboratively managed by a group of fringe communities and has been particularly successful at the Avu lagoon (Ahmed and Gasparatos 2020). However, it is evident that the participatory approach has not been successfully adopted everywhere. At Fosu lagoon stakeholder groups were not involved in decision making regarding lagoon conservation, which created apathy and sense of injustice (Armah et al. 2010). Successful examples of participatory management often work conjointly with an acknowledgement of traditional regulations and regard for indigenous practices. Many West African lagoons have traditionally been managed by tribal laws and taboos. This is commonly manifest in traditional methods to manage fisheries such as a closed fishing season as well as taboo days, when entering the lagoon is not allowed (Koranteng et al. 2000, Darkwa and Smardon 2010, Setondji et al. 2021). However, a breakdown in the effectiveness of these traditional and cultural management rules associated with the loss of the spiritual importance of lagoons has been highlighted as contributing to the erosion of effective resource management (Owusu Boadi and Kuitunen 2002, Stoop et al. 2016).

6.3 Solutions

Solutions highlighted in the scoping study are focused on reforestation programmes to restore lagoon vegetation and civil engineering projects that involve alteration of the physical environment and hydrology of lagoons. Solutions may be led by both the government and non-governmental sectors as well as through partnerships. Reforestation programmes for mangroves have been instigated across the region with varying effectiveness, often hampered by over-harvesting of new plantations (Darkwa and Smardon 2010). In Benin, some mangrove restoration programmes have failed due to removal for acadjas (Zanvo et al. 2021). In Ghana, conservation and restoration programmes such as those at Songor and Keta lagoons have not been very successful and failed largely due to a lack of understanding over access, ownership and land tenure regimes (Asante et al. 2017). The Korle Lagoon Ecological Restoration Project (KLERP) is unusual in that is focused more broadly on the restoration of not only the lagoon but also its tributary river system in the metropolitan area of Accra (Opec fund for international development). Civil engineering projects, such as dredging, lagoon opening, managed drainage and damming are common at lagoons across the region to provide solutions to flooding, maintaining transportation and enhancing water quality. Dredging is used to improve transportation for boats and ships and to prevent flooding. Lake Nokue is dredged partly to prevent floods in Cotonou and Porto-Novo (Djihouessi et al. 2017). The Korle lagoon is dredged to prevent floods and to facilitate flushing into the sea (Karley 2009). At the Senegal lagoon creation of an opening to the ocean 25 km from the natural one was undertaken to prevent flooding (Bouvy et al. 2010). There are examples from Ghana where managed opening of the lagoon barrier has been undertaken to prevent flooding of residential areas (Davies-Vollum et al. 2019). At the Senegal lagoon, damming is undertaken to reduce saltwater inflow and maintain freshwater for irrigation (Cogels and Varis 2001). A sea outfall project in Abidjan was established to improve water quality in Ebrie lagoon with drains to collect and forward city waste into the Atlantic Ocean, but this has not been successful (Adingra and Arfi 1998). Coastal hard engineering has also been employed at lagoons as a solution to flooding and erosion, for example a sea defence wall has been constructed at Keta lagoon to prevent flooding and erosion (Boateng 2012). Educational initiatives in lagoon communities to improve understanding of environmental health was another solution offered (Mensah 2019a) but it is not widely reported.

7 Discussion

This scoping study identified and reviewed the available literature on coastal lagoons in West Africa with the aims of identifying gaps in knowledge and distilling information currently available to inform management of these environments. The study drew on similar work that was conducted on lagoons in Europe (Newton et al. 2014) and North Africa (El Mahrad et al. 2020). Use of the DAPSI(W)R(M) framework enabled a structured

and detailed analysis of the literature. Key drivers and activities were established as the use of lagoon resources and the expansion of lagoon settlements. These have created pressures around waste, resource over-consumption and urban growth in addition to the pressure of climate change. Resultant state changes are seen in the degradation of lagoon water quality and habitats with impacts on the health of lagoon organisms (most significantly fish), and human health and wellbeing. Responses to state changes have come in the form of legislation, management approaches and solutions that focus on ecosystem restoration and civil engineering works. The study enabled an understanding of themes and topics emphasised in prior work, the identification of gaps in knowledge where future work would be beneficial and key recommendations for lagoon management.

7.1 Emphasis of prior work

The importance of lagoons located along the West African coastline and within the Guinea Current Large Marine Ecosystem (GCLME) is evident in the diversity of lagoon-related topics identified in the scoping study. However, the scoping study revealed both geographic and thematic emphases on the study of lagoons in the region. Many of the sources available for lagoons located along the Guinea Current Large Marine Ecosystem (GCLME) focus on the Ivory Coast-Ghana-Togo-Benin-Nigeria corridor with research from Ghana and Nigeria dominating sources. Based on the number of times they appeared in the literature, two major themes emerged: fish health/fisheries and lagoon water quality. All countries within scope for the study had sources that referred to fishing. The emphasis on fish and fisheries is not surprising given their importance to West Africa both economically and as a food staple. Small-scale and artisanal fishing are the activities around which many traditional lagoon communities are founded and fisheries-related livelihoods underpin their health and wellbeing. Identified problems of over-fishing, fish contamination, decreased catch, and related conflicts of fishing rights are all risks for the sustainability of those communities. Poor water quality is the most commonly cited pressure and is the cause of much of the state change and impacts noted in sources. The implication is that there is a lack of regulation for pollutants and contaminants from industrial, agricultural and domestic sources. Deforestation and the loss of mangroves also featured in the sources with legislation to protect mangroves featuring in the literature but also an acknowledgement that conservation programmes have not necessarily been successful.

7.2 Knowledge gaps

The scoping study reveals both geographic and content gaps in the current knowledge and understanding of West African lagoons. There is a geographic gap with limited research available on lagoons in Senegal, Liberia and Côte d'Ivoire. Literature sourced that included reference to lagoons in Gambia, Guinea-Bissau and Guinea and Sierra Leone was minimal and deemed out of scope for this study based on definitions used in the scoping exercise. This partly reflects the predominance of lagoons along the Gulf of Guinea from Liberia to Nigeria, west of the Niger delta. There are a few identifiable lagoons along the Guinea-Bissau, Guinea, and Gambian coastlines but estuaries are more predominant, linked to large rivers such as the River Gambie and River Casamance. Lagoons are present along some parts of the coastline in Sierra Leone but sources identified did not meet the criteria for this scoping study. Liberian lagoons are represented in the literature, although not commonly. Much of the literature that is available for lagoons in the region tends to focus on a specific lagoon or, less commonly, multiple lagoons within the same country.

Key content gaps were recognised around certain types of waste, the significance of lagoons as wetlands and the impacts of climate change. A lack of holistic and multidisciplinary understanding of lagoons is also evident as well as a deficit of literature that includes information about the responses to the pressures, state changes and impacts identified at lagoons. Plastic pollution has become a problem in coastal environments across the globe in recent years, yet it has largely been ignored in the literature describing problems of waste in West African lagoons. Given the current high profile of marine plastics and a recent global review of plastics in lagoons (Garces-Ordonez et al. 2022) we would anticipate an increase in research on this. Electronic waste (e-waste) is also rarely noted despite increasing concern over how it is managed in LEDCs and its potential for the release of toxic substances (Sthiannopkao and Wong 2013). Many lagoons function as key coastal wetlands, as evidenced by their inclusion in the Ramsar convention. There is an increasing understanding of coastal wetlands as a carbon sink and their role in coastal blue carbon sequestration and conservation (Bryan et al. 2020) due to their high productivity. However, although the significance of wetlands for birdlife is evident from this study, their critical role of carbon storage is not surfaced in the literature. The extent of sources that focus on the impacts of climate change on lagoonal environments is limited and understanding how climate change effects lagoon has apparently not been prioritised. This is despite the vulnerability of lagoons and associated communities to the impacts of sea level rise and the effect that changes in

weather patterns can have on lagoon systems and cycles (Davies-Vollum et al. 2021). It has been suggested that concern over climate change might be de-emphasised because economic impacts are felt more acutely than climate related ones at lagoons (Koomson et al. 2022) with subsequent focus on what are seen as the most pressing issues. The challenge of the multi-faceted pressures and impacts revealed in the scoping study requires multi-faceted solutions and consideration from multiple disciplinary perspectives. Similar to Mehrad et al.'s study of North African lagoons (El Mahrad et al. 2020) there is a lack of multi- and interdisciplinary studies present in the literature for West African lagoons. Research on lagoons in West Africa is almost all uni-dimensional, focusing on one aspect of the multifarious problems lagoon communities face. There are limited studies to understand how the combined inter-sectional impacts of these challenges affect lagoons and their communities. Studies that compare and contrast lagoons between countries are rare. Linkages to global frameworks, such as the UN sustainable development goals, are also rare. Yet such studies are required to understand the interplay of impacts to inform and establish effective policy and governance that will underpin the sustainability of lagoons. Finally, although many of the articles describe the drivers, activities, state change and impacts at lagoons, there is a lack of coverage on the responses to these. Three countries in the study (Nigeria, Togo and Liberia) had no responses to impacts apparent in the literature and the common approach in many sources is to present problems without consideration of how these problems have been or might be addressed. The lack of responses and solutions offered represents a significant gap in the application of academic studies to inform the management of lagoons.

7.3 Future lines of enquiry

The gaps identified represent opportunities for future lines of enquiry into the sustainability of coastal lagoons in West Africa. Studies that focus on the pressures and impacts of plastic and electronic waste streams that affect lagoons are currently not commonly found in the literature although a body of work pertaining to plastic pollution is emerging (Garces-Ordonez et al. 2022). Research on the impact of climate change on West African lagoons is limited. Further work that addresses pressures resulting from climate change, together with possible adaptations and mitigations for lagoons and their populations, is necessary for securing lagoon sustainability. There is also a need for integrated, transdisciplinary studies that look at the inter-connectedness of pressures to better understand how they influence state changes and impacts, specifically how climate change intersects with development related stressors and how this impacts the lived experience of lagoon communities. Future work would also benefit from having a greater focus on and inclusion of responses to state changes and impacts that can then inform management. Although presenting the activities and the state changes and the impacts they pose to lagoons is an important first step, understanding how they have been addressed, highlighting both success and failures, adds practical value and allows application of the study. Studies that address this would help to better understand common issues and help identify successful solutions to them.

7.4 Management recommendations

Despite the gap in management recommendations and solutions that was evident in the scoping study there are some recommendations that can be gleaned from the study. Legislation described has been predominantly punitive although there is evidence for increasing resource conservation and co-management of lagoon resources. For lagoon communities who are highly dependent on local resources, effective resource management is critical and it is increasingly understood that successful resource management is predicated on the participation of local communities and stakeholders (Dyer et al. 2014, Metcalfe et al. 2016) Sources evidenced examples of conflicts relating to resource use emphasising the need to understand local conditions, customs and land ownership. The need for improved regulation of lagoon water quality through better management of pollutants, contaminants and waste entering lagoons from a diverse variety of sources is evident in all countries in the study. This includes managing agricultural waste; heavy metal pollution from industrial and waste dumps; electronic waste; solid waste and the emergence of plastics as a significant constituent of waste found in lagoons. Regulation can only be successful if there is adequate infrastructure for collection of waste and recycling as well as for drainage of run off and sewerage. Ocean flushing has been used in responses to poor lagoon water quality, however this is not a panacea. An integrated approach to the whole drainage system from lagoon catchment to the nature of outlets to ocean, and which accounts for engineered structures, such as dams on lagoon tributaries and drainage channels, is critical to address water quality. Lagoons are prevalent across the GCLME but there are very few studies that consider lagoons in more than one country and indeed many focus on a single lagoon. Cooperation between countries, especially where lagoons cross national boundaries, is recommended for future work (Povilanskas and Razinkovas-Baziukas 2023).

7.5 Drawbacks

A scoping study such as this has drawbacks. The terminology used for coastal lagoons varies throughout the world (El Mahrad et al. 2020). Indeed, this is seen throughout West Africa where the terms lake and lagoon are used interchangeably. The term estuary is also sometimes used for lagoons that have significant connection to the ocean and the phrase coastal wetlands might be used to refer to aspects of lagoon environments, especially in reference to Ramsar status. The use of multiple terms for lagoons can mean that some relevant articles about lagoons were not detected, limiting the scope of the study. There is also a challenge in accessing literature not published in English. This exercise was restricted to articles accessible in English and meant that some work from Côte d'Ivoire and Benin, where the French language predominates, will not have been included.

Any scoping study that attempts to understand the current state of knowledge of a subject is date limited. This study was initially completed in 2021. Since then, there have been lagoon-related publications of note from West Africa, some of which are already starting to address knowledge gaps that were identified in this study. The first study to focus on the incidence of plastic waste in lagoons in the region looks at microplastics in the Lagos lagoon (Dada and Bello 2023). Other recent studies add to the body of work on fisheries as well as pollution due to industrial and agricultural waste (Emmanuel et al. 2023, Mahu et al. 2023, Zonkpoedjre et al. 2023). Additional work related to climate change has focused on adaptations to mitigate flooding (Brempong et al. 2023). The role of West African lagoons in sequestering carbon remains unexplored. Recent work that provides examples of responses to lagoon stressors include a study of the introduction of mangrove reforestation as an alternative livelihood at Keta lagoon (Sekey et al. 2023), the co-management of mangroves in Togo-Benin (Gnansounou et al. 2022) and consideration of land rights and property ownership of lagoon communities in Benin (Setondji et al. 2022) and at the Ebrie lagoon (Irit 2022). Multi-faceted, intersectional and geographically broad approaches to the study of lagoons in the region remain rare. Notable exceptions include a review of stressors impacting lagoons with case studies from Nigeria and Ghana (Davies-Vollum et al. 2022), a study of management of environmental challenges across eleven lagoons in Ghana (Takyi et al. 2022) and work on interdisciplinary approaches to coastal management in West Africa (Dada et al. 2021) that directly references lagoons.

8 Conclusion

Lagoons are a critical coastal environment in West Africa that are experiencing major state changes as a result of resource over-use and expansion of settlements in addition to the impacts of climate change. These drivers have resulted in the degradation of lagoon ecosystems and water quality as well as the decline of keystone species of fish and mangroves, with resultant impacts on human health and wellbeing. Published studies have tended to emphasise environmental stressors and changes at lagoons with less examination of the responses and approaches employed to address them. Responses that have been reported include legislation that has been predominantly punitive and solutions that have gravitated towards ecosystem restoration and engineering of the physical environment. However, there is increasing evidence of overtly including lagoon communities in responses with some examples of participatory management, alternative livelihoods and land rights. Consideration of the interconnectedness of lagoon stressors and the need for responses that take a multi-faceted approaches are rare as are studies that consider multiple lagoons. Future studies that help to better understand the complexity and intersection of stressors felt at lagoons to inform responses and be applied to their management must be underpinned by such integrated and holistic approaches. Projects such as this study can be utilised to offer a breadth of understanding to support lagoon management across a region, pinpointing common problems whilst highlighting differences that extend scope beyond the national and local.

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Sian Davies-Vollum directed the study and wrote the article; Daniel Koomson undertook the scoping study; Debadayita Raha edited and contributed to the writing of the article.

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Availability of data and materials
Tables submitted as part of the main paper show the scoping data on which conclusions are based. Full details of the scoping study and the charting exercise are being made available through the University of Northampton.

Declarations

Ethics approval and consent to participate
Not applicable, this is a scoping study of published literature.

Consent for publication
Not applicable.

Competing interests
The authors have no competing interests to declare that are relevant to the content of this article.

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