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COMPARATIVE ANALYSIS OF ECOSYSTEM SERVICE DELIVERY BETWEEN TWO COASTAL LAGOONS IN GHANA

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ABSTRACT. The integration of ES into global policies represents a significant step towards harmonising sustainability and growth and unifying dialogues on biodiversity and sustainable development to benefit humanity. Consistent assessment of the availability of ES is vital to enable ongoing monitoring and support sustainable natural resource management and decision-making. This study was conducted to comparatively analyse the ecosystem service delivery between two coastal lagoons in Ghana. The Millennium Ecosystem Assessment (MEA) and Marine Ecosystem Services Assessment Tool (MESAT) scales were used in the study. The paper was based on the positivist paradigm and employed inferential statistics with SPSS v23 for data analysis. The results indicate no statistical differences between the Fosu and Muni lagoons in terms of their ecosystem service delivery; the null hypothesis is accepted for the two ecosystem service scales used and confirms that Fosu and the Muni Lagoons are similar in their deliveries of ecosystem services. The relationship between ES and human well-being is complex due to the interplay between social and ecological systems. To address coastal issues and develop management plans, the study proposes using MESAT and MEA for evaluation and solution provisioning. It further recommends expanding stakeholder and decision-maker involvement in lagoon management to promote sustainability and enhance stakeholder participation in decision-making.

Keywords: cultural services; Muni and Fosu Lagoons; provisioning services; regulatory services; social-ecological system; supporting services.

INTRODUCTION

Coastal ecosystems have an important role in human wellbeing by offering a variety of ES. These services are described as the tangible and intangible goods provided to humanity

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by nature's processes and operations (MEA, 2005). However, human activity has generated various global developments, such as climate change, terrain alterations, diminished biodiversity and ecological degradation, putting human standards of life in danger all over the world. According to Rüdisser *et al.* (2020), the ES concept focuses on the connections between people and their environment and includes ecological and social factors. An ecosystem, according to D'Ottavio *et al.* (2018), is an unpredictable network of plant, animal and microbe communities functioning as a functional unit, of which humans are an intrinsic component. ES are products and services that are required for sustaining natural environmental conditions and utilities. They can be obtained directly or indirectly through the structure, processes and activities of the ecosystem (Huang *et al.*, 2023). The MEA (2005) defined ES as the benefits that people derived from ecosystems, and this definition attained scientific agreement while also raising the public's consciousness of the importance of nature (MEA, 2005). The concept of ES was developed to emphasise how important the functionality of ecosystems is to the wellbeing of humans (Rova and Pranovi, 2022).

As our world changes, evidence-based strategies and policies are crucial to protect biodiversity and natural capital; coastal ecosystems are crucial for preserving both the biodiversity of the world and human well-being. The world's most significant and productive ecosystems are lagoons, which offer humans a wide range of special goods and services (do Amaral Camara Lima *et al.*, 2023). Coastal lagoons have been referred to in the literature as the kidneys of the landscape because of their role in storing, absorbing and changing pollutants from the environment before they enter waterbodies (Ekumah *et al.*, 2020). The structure and ecological health of an ecosystem is crucial for its operation and the provision of ecosystem services. These services are the benefits that individuals receive from ecosystems. Coastal lagoons are shallow aquatic environments located at the intersection of coastal terrestrial and marine ecosystems. They may be continuously exposed to the nearby sea or momentarily cut off by depositional barriers (Van Niekerk *et al.*, 2020). Coastal lagoons make up 13% of the world's coastlines and are highly productive ecosystems that offer numerous ecological and economic benefits. These benefits include providing habitats for mangroves, salt marshes and seagrass and serving as flood mitigation channels. Lagoon ecosystem conservation has gained more attention in recent years, as stated by ecologists and geographers, with growing urgency (Suresh *et al.*, 2021). In modern times, it is widely recognised that lagoon ecosystems serve various ecological purposes, such as regulating the hydrological cycle and acting as natural sanctuaries for aquatic flora and fauna. Lagoons are also considered valuable economic assets with high conservation values because of their significant benefits to the welfare of dependent communities (Clara *et al.*, 2018).

Along Ghana's coastline, there are more than 90 lagoons of various sizes, many of which are surrounded by

mangrove swamps (Amadu, 2021). These Lagoons are covered with intertidal mud or sand flats. Some of the notable and prominent coastal lagoons in Ghana are Chemu, Fosu, Korle, Kpeshie, Muni-Pomadze and Sakumo Lagoons. Most of these lagoons constitute crucial ecosystems suitable for a variety of crabs, fish, shrimps, molluscs and polychaete species. According to D'Alpaos and D'Alpaos (2021), coastal lagoon ecosystems contribute to a sense of place, improve biodiversity, support commercial fisheries, shield coastal areas from storms and erosion, generate income from ecotourism and function as effective natural carbon sinks that help counteract CO_2 emissions and combat climate change. The Fosu and Muni Lagoons co-occurr on the central coastline of Ghana and have similar environmental conditions. The two lagoons are of great importance to the culture and traditional activities of the indigenous people. During the Fetu Festival, Cape Coast locals breach the sand bar that separates the Fosu lagoon from the Atlantic Ocean. On the other hand, the Muni lagoon's catchment area is the location of the Yenku Forest Reserve, which provides a habitat for several animals, including deer proudly used for the Aboakyer Festival. Aside from the cultural relevance of the lagoons, they also deliver all other types of ecosystem services. Despite their striking similarities, no study has compared their delivery of ecosystem services). Even though works on ecosystem service are well documented in Ghana (e.g., Agula *et al.*, 2019; Amoah and Korle, 2020; Koo *et al.*, 2020; Murray *et al.*, 2017; Nartey., 2023; Obeng *et al.*, 2021; Osman *et al.*, 2023), little research has been done to compare the service delivery of lagoons in Ghana. A catalogue of studies looked at volunteerism in ecosystem restoration in the Muni lagoon (Osman *et al.*, 2023). There are two studies on enhancing healthy ecosystems and local community preferences in northern Ghana (Agula *et al.*, 2019; Obeng *et al.*, 2021). Some researchers have been investigating the effects of urban expansion on the availability of green spaces and how it affects the provision of ES in the Accra Metropolis (Puplampu *et al.*, 2021). In addition, there have been studies on the potential future supplies of cultural ES in the coastal landscapes of Southwestern Ghana, West Africa (Kankam *et al.*, 2021). Moreover, some researchers have examined the role of traditional ecological knowledge in managing ES in four rural communities in Northern Ghana (Boafo *et al.*, 2016). There have also been investigations into the trade-offs and synergies between food and fodder production and other ES in actively restored forests, natural forests and agroforestry systems in Ghana (Damptey *et al.*, 2021). Limited attention has been given to quantifying and comparing the delivery of ES in coastal lagoons in Ghana, as most research has focused on forest resources.

Thus, this study compares the delivery of ES between two lagoons. Traditional councils and municipal assemblies can use the information provided by the study to design plans or policy regulations that increase and promote the ES of the two lagoons. The study aims to identify the ecosystem functions that are under greatest

anthropogenic pressure. This information can then be used to manage interventions more effectively. Policymakers can implement appropriate regulations in areas with a larger recreation flow (Singh *et al.*, 2022) to reduce environmental pressure caused by over-exploitation like encroachment due to urban expansion. These lagoons have cultural significance, and it is essential to preserve them by reducing environmental pressure. The research question that guided the study was, are the two coastal lagoons delivering their expected ecosystem services, or what is the level of delivery of ES between the Fosu and Muni Lagoons?

The study sought to test the following hypotheses:

H_0: There is no statistically significant difference between the delivery of ES by the Fosu and Muni Lagoons.

H_1: There is a statistically significant difference between the delivery of ES by the Fosu and Muni Lagoons.

Theory of Social-ecological Systems

The Social-Ecological System (SES) framework, developed by Elinor Ostrom and colleagues, is a commonly-used theory to describe the interactions between humans and nature in ecosystems (Ostrom, 2009; McGinnis and Ostrom, 2014). This framework has a generalised structure that can be applied to a wide range of SESs, making it a useful tool for comparing processes and entities across different systems. The ecological system is divided into two primary components: "resource systems", which consist of sets of "resource units". The social system is made up of two parts: governance systems and actors. The governance systems set the rules and conditions of the system, while the actors participate in the system. Action situations occur when the two systems interact, and actors make choices. This study uses the SES theory to compare the delivery of ES in two coastal lagoons of cultural significance in Ghana. The aim is to prevent poor decision-making regarding ecosystem service delivery. Delivering ES is complex and involves interactions across SESs. This paper is grounded in the theory of SESs and draws on various sources, including Fedele *et al.* (2017), Fischer *et al.* (2015) and Bennett *et al.* (2015).

To ensure effective management and policies for ecosystem services, it is essential to identify and understand the interactions that play a key role in achieving specific desired outcomes. The relationship between ecological and social systems is inseparable. As a result, ES evaluation must take into account both the intricate relationships between ecosystem processes, structures, and capacities, as well as the distribution and assessment of benefits among stakeholders with varying requirements and ambitions. To achieve this, it is necessary to comprehend the multifaceted links between ecosystem processes and benefits for human wellbeing. There are numerous approaches to define and analyze the complicated interaction between human actions, environmental variables and ES. One approach used by many researchers is the SES approach, which focuses on spatial characteristics and correlation.

Wang *et al.* (2021) found a robust relationship between topographic

gradients, land-use patterns, and ES (ES) provisioning. Similarly, Rüdisser *et al.* (2020) found land-use changes as the key driver of ES provision changes in the Manas region in China. They also used a cluster analysis to delineate regions with similar ES bundles. In this study, an attempt is made to analyse various ESin the context of the Muni-Pomadze and Fosu Lagoons. We evaluate the lagoons based on the four principal components of service delivery: regulating, supporting, recreation and provision (MEA, 2005). Provisioning services are the direct products and material benefits obtained from ecosystems, such as food resources, fibre, water, fuel, wood, biochemical and genetic resources. Wetlands, as described by Hopkinson *et al.* (2019), support perennial or seasonal fisheries, which are crucial for both residents and migratory birds. The lagoon environment also provides a sanctuary for a diverse range of species, such as birds, reptiles, fish, mammals, amphibians and invertebrates (Maxwell, 2019).

Regulating services are the benefits derived from the ecosystem's management and control mechanisms. Ecosystems provide various regulating procedures and services, such as climate regulation, disease management, flood control, water purification and pollination (Huynh *et al.*, 2022). The term "cultural services or recreation" refers to the intangible benefits received from ecosystems, such as leisure and ecotourism, educational benefits, spiritual and religious advantages, motivational and inspirational value and cultural heritage linked to a certain ecosystem type. Wetlands provide a place for people to relax and have fun, both in the neighbourhood and while visiting the region. A protected wetland region provides opportunities for intellectual, spiritual and cultural experiences (Huynh *et al.*, 2022). Supporting services indirectly affect people in the long term. Unlike the other three groups, they provide services required for the creation of other ecosystem services. Examples of supporting services include primary production, nitrogen cycling and soil formation (Adamu, 2019).

MATERIALS AND METHODS

Study Area

The research focused on two coastal lagoons, Fosu and Muni, that are of cultural significance in Ghana. These lagoons are in the central coastal plains of Ghana. This section provides detailed information about the study areas, including their locations, vegetation, climates and hydrogeomorphologies. Additionally, the materials and methods used for the study are discussed in this section.

Fosu Lagoon

Ghana has a coastline that extends over 550 km and is divided into three zones based on geomorphologic features. These zones include the eastern, central and western regions (Boateng *et al.*, 2012). The Fosu Lagoon is located on the central coastline, specifically in the Cape Coast Metropolis. The coastline in this area is considered a medium-energy environment (Boateng *et al.*, 2012). The shoreline is characterised by rocky headlands, sand bars and spits, which

enclose coastal lagoons. The Fosu Lagoon barrier area is mainly made up of sandy shorelines, with some rocky outcrops found on both the eastern side of the Cape Coast Castle and the west around the Sweet River estuary. The Cape Coast Metropolis is a low-lying area with predominantly sandy characteristics surrounded by the Fosu Lagoon.

A study by Dadson *et al.* (2016) summarises the region's geomorphology as follows: the areas extending westwards to the beach around the Cape Coast Regional Office are rocky. The sandy beach continues westwards around the Cape Coast Castle after the rocky beach around the Cape Coast Regional Office. From the Cape Coast Castle, the sandy beach stretches westwards across the Kakum or Sweet River estuary to the Elmina Castle area, where a rocky beach is found. The rocky beach found around the River Kakum estuary has been named "coffee rocks" by Dei (1975) for exhibiting the colour of coffee (Dadson *et al.*, 2016, *Figure 1*). The Cape Coast Metropolis in the Central Region of Ghana lies between latitudes 5°6'19.26N and 1°14'47.76"W. It is bounded on the east by the Abura Asebu Kwamankese District, on the west by the Komenda Edina Eguafo Abrem (KEEA) District, on the south by the Gulf of Guinea and the north by the Twifo Heman Lower Denkyira District. The metropolis covers an area of 122 km^2, making it the smallest metropolis in the country (GSS, 2021). The vegetation consists primarily of secondary forests, with thickets and shrubs growing up to an average height of 4.5 meters. The metropolis has a 13-km-long coastline. Temperatures range between 24°C and 32°C, with humidity levels ranging from 60% to 80%. There are two rainy seasons, with the highest rainfall occurring in June and October. The annual precipitation ranges from 90 to 110 mm along the coast and 110 to 160 mm inland. From November to February, the area experiences dry periods, known as harmattan (GMA, 2020). The area is mostly hilly, with valleys between the hills, and the highest point is around 60 m above sea level. The main streams or rivers in the area are Siwere and Kakum, which flow into the Fosu and Abakam Lagoons. Some flood-prone areas within the study area are located below 60 m above sea level.

Muni Lagoon

Muni-Pomadze Ramsar site, also known as Muni Lagoon, is a closed coastal lagoon in Winneba, Ghana's central region. On August 14, 1992, the site was classified as a Ramsar site. Muni Lagoon is located adjacent to the town of Winneba on Ghana's central coastline, approximately 60 km west of Accra (Eze *et al.*, 2022). The lagoon is separated from the ocean by a 2-km-long beach bar that is permanently connected to land on its eastern side. The lagoon has a total area of 9,461 ha, which varies in size based on seasonality. The lagoon's size ranges from 100 ha in the dry season to over 1,000 ha in the wet season.

The Muni-Pomadze Ramsar site is characterised by various geomorphic features, including a dune that acts as a barrier between the lagoon and the ocean. The site boasts a diverse range of flora and fauna, all of which play vital roles in the ecosystem.

Additionally, the area includes the Yenku Forest Reserves A and B, which serve as hunting grounds for 'bushbuck' during the annual Aboakyir Festival of the Effutu people (Gordon *et al.*, 2000). The site is subject to tidal and seasonal inundation, with scrub, farmland and marsh areas affected by these conditions. The lagoon's sandy shore serves as a nesting location for sea turtles as well as a feeding and breeding ground for over 23,000 water birds such as terns, waders, herons and egrets.

The Ramsar site is a habitat for around 75 species of butterflies. The eastern part of the site is covered by dense mangroves, which are used as fuel wood for fish smoking by the nearby communities. There is a narrow strip of dunes separating the lagoon from the sea, which has a coconut plantation, attracting tourists and birdwatchers. The site is used for various human activities such as farming, cattle grazing, hunting and fishing. The Yenku hills and the Egyasimanku hills border the catchment. In 2000, the site had 53% natural vegetation, 32.5% agricultural lands and 12.6% residential development from the 11 communities in the area (Gordon *et al.*, 2000). In 2010, Atampugre reported that the forest cover in the Municipality was 31.9%, with 20% agricultural land and 40.5% built-up area.

Fishing, wholesale and retail services, manufacturing, salt mining (known as white gold), crop farming, and agro-processing are the key economic activities in the area. The municipality's main economic activity are fishing and farming, primarily maize and cassava. Other minor activities in the area include hunting (typically done by the Effutu people), cattle grazing, sand, clay, and gravel mining, salt winning, and charcoal making. Refer to *Figure 2* for the map of the study area.

Research Design

This study aimed to compare the delivery of ES by the Fosu and the Muni Lagoons, both of which are located within the central coast region of Ghana. It was a quantitative study guided by empirical science, which believes that theories govern the world and should be tested to gain a comprehensive understanding of it (Borgstede and Scholz, 2021). The study is based on the positivist worldview, which serves as the philosophical foundation for the research.

The positivist approach focuses on investigating patterns and connections between social factors to make accurate predictions about society and social change. According to positivists, this can be best achieved through quantitative methods (Creswell and Creswell, 2017). The quantitative methods were applied to ensure reliable and precise data for generalisation about service delivery. The decision was also influenced by the need for future replicability of the study and to maintain objectivity towards the collected data. The study followed a descriptive case study comparing the service delivery of the Fosu and Muni Lagoons in Ghana. According to Aggarwal and Ranganathan (2019), the descriptive case study approach provides in-depth, multi-faceted analyses of complex challenges in real-life contexts.

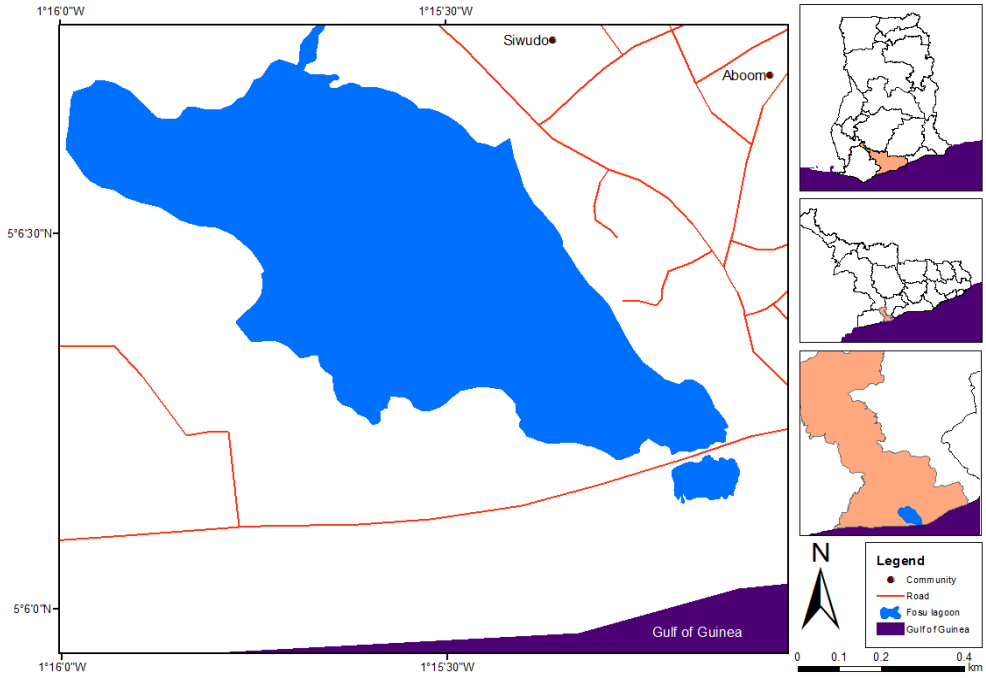

Figure 1 – Fosu Lagoon in national and regional contexts

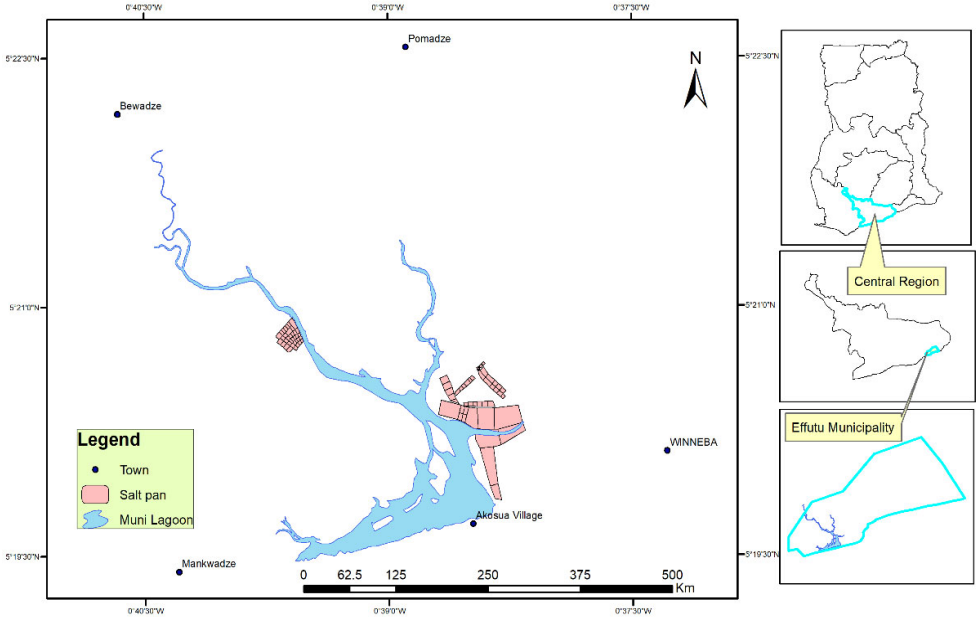

Figure 2 – Muni Lagoon in regional and national contexts

Population and Sampling

The study was conducted on the indigenes of Cape Coast and Winneba, who provided data for the Fosu and Muni Lagoons, respectively. The participants mainly consisted of fishermen and other non-fishing residents. It is not clear what the population size is for this specific group of people, who are the focus of this study. Cochran (1977) suggests that when both the population size and population proportions are unknown, the sample size (n) should be calculated using the following equation:

$$the\ n = \frac{z^2}{4e^2} \quad (1)$$

where n = sample size; p = the population proportions; e = acceptable sampling error (e=0.05); and z = z value at reliability level or significance level.

To ensure a reliability level of 95% or a significance level of 0.05, the formula requires a value of z = 1.96 (Cochran, 1977). Using this value, the formula was applied to calculate a minimum sample size of 384.16 individuals for the study. However, to increase the validity of the findings and generalise the results, the sample size was left open for an increase, with an established minimum sample size of 384 as the floor.

To account for the ecosystem delivery of Muni Lagoon, a sample size of 937 was established for the locals in Winneba, and a sample size of 833 was established for locals in Cape Coast to account for the ecosystem delivery of Fosu Lagoon. The respondents for both lagoons were selected using convenience sampling.

Instrumentation,
Data Collection and Analysis

The delivery of ES by the Fosu and Muni Lagoons was evaluated using system assessment scales. These scales were based on the variables in the United Nations' Millennium Ecosystem Assessment (MEA) Framework (2005) and the Marine ES Assessment Tool (MESAT), which was modified after Inácio *et al.* (2019) work. A questionnaire was used as the instrument, which consisted of closed-ended items for socio-demographic variables and a Likert format for the ecosystem service items. The data were analysed using SPSS version 23, with frequencies and percentages as the units of analysis for the socio-demographic characteristics of respondents. An independent samples t-test was used to explore the statistical differences in the deliveries of ES of the two lagoons.

The assessment of reliability using Cronbach's Alpha showed that the internal consistency of the scales was very good. In terms of the MEA subscales, the regulating service scale had a Cronbach's Alpha of 0.807 (N = 6), the supporting service scale had a Cronbach's Alpha of 0.845 (N = 5), the recreation service scale had a Cronbach's Alpha of 0.886 (N = 6). The provisioning service scale had a Cronbach's Alpha of 0.896 (N = 9). The combined regulating, supporting, recreation and provisioning services scales, which make up the overall MEA scale, showed even better internal consistency with a Cronbach's Alpha of 0.954 across all 26 items. As for the MESAT subscales, the provisioning services scale had a Cronbach's Alpha of

0.876 (N = 10), the regulating and maintenance service scale had a Cronbach's Alpha of 0.923 (N = 11) and the cultural service scale had a Cronbach's Alpha of 0.874 (N = 10).

RESULTS

To gain a better understanding of the research results, the study considered the socio-demographic characteristics of the survey participants. Previous research has shown that there is a connection between people's demographics and their attitudes and perceptions towards certain events (Mackenzie, 2014). The findings of the demographic characteristics of the respondents are presented in *Table 1*. The demographic data of the study area were crucial to the researcher as they provided a diverse range of participants based on their age, academic level, income and household information, resulting in a comprehensive view of the research topic. The survey results show that males made up the majority (65.31%) of the respondents. Most respondents were under 50 years old. Most households had five or fewer people living in them. Additionally, most respondents had a monthly income of 500 Cedis or less. Most respondents had a pre-tertiary level of education, with basic education being the most common. Less than 10% of respondents had never received formal education. The study suggests that education plays a significant role in one's understanding and perspective. Therefore, the higher the level of education, the greater the knowledge. The demographic characteristics of the respondents indicate that they have a good understanding of the issues being studied and can provide valuable data.

Differences in the delivery of ES between the Fosu and Muni Lagoons

Differences in ES Between the Fosu and Muni Lagoons Based on the Millenium Ecosystem Assessment (MEA) Scale

As coastal lagoons have striking similarities, the study sought to explore whether differences in their deliveries of ES exist. An independent samples t-test was conducted to explore the statistical differences between the ecosystem service delivery by the Fosu and the Muni Lagoons. Considering the types of ecosystem services, the study explored the statistical differences between the two lagoons in terms of all four types of ecosystem services: regulating, supporting, recreation and provision services. As shown in *Table 2*, the study revealed that all the data did not violate the assumption of equality of variances as Levene's test of equality of variances found for all the types of ES were not significant; regulating services ($F = 1.237$; $p = 0.266$), supporting ($F = 0.249$; $p = 0.618$), recreation ($F = 1.004$; $p = 0.316$) and provisioning ($F = 0.313$; $p = 0.576$).

Many of the basic functions that people rely on are provided by ecosystems. Plants purify the air and water, microorganisms breakdown trash, bees pollinate flowers, and tree roots hold soil in place to avoid erosion (Christmann, 2022). All of these processes interact to keep ecosystems clean, sustainable, functional, and adaptable to change. The benefit supplied by ecological processes that moderate natural events is known as a

regulating service. Pollination, decomposition, water purification, erosion and flood management, carbon storage, and climate regulation are all examples of regulating services. In terms of the delivery of regulating services, the study found no statistically significant differences between the Fosu Lagoon (M = 3.4468; SD = 0.86385) and the Muni Lagoon (M = 3.4399; SD = 0.90671).

Table 1 – Socio-demographic Characteristics of Respondents

Variable	Response	Fosu Lagoon		Muni Lagoon		Total	
		Freq.	%	Freq.	%	Freq.	%
Gender of respondent	Male	557	66.87	599	63.93	1156	65.31
	Female	276	33.13	338	36.07	614	34.69
Age of respondent	20–30 years	160	19.21	205	21.88	365	20.62
	31–40 years	207	24.85	258	27.53	465	26.27
	41–50 years	201	24.13	261	27.85	462	26.10
	51–60 years	156	18.73	187	19.96	343	19.38
	Over 60 years	109	13.09	26	2.77	135	7.63
Respondent's household size	Less than 5 persons	475	57.02	441	47.07	916	51.75
	6–10 persons	230	27.61	287	30.63	517	29.21
	More than 10 persons	128	15.37	209	22.31	337	19.04
Average monthly income	Up to 500 Cedis	521	62.55	507	54.11	1028	58.08
	501–1000 cedis	205	24.61	312	33.30	517	29.21
	Over 1000 cedis	107	12.85	118	12.59	225	12.71
Respondent's level of education	No formal education	89	10.68	87	9.28	176	9.94
	Primary school education	331	39.74	331	35.33	662	37.40
	Junior high school educ.	269	32.29	350	37.35	619	34.97
	Senior high school educ.	123	14.77	159	16.97	282	15.93
	Tertiary education	21	2.52	10	1.07	31	1.75
Total		833	100	937	100	1770	100

Source: Field data (2023)

Table 2 – Group Statistics of MEA and ES Scales

Service	Lagoon	N	Mean	Std. D	SEM
Regulating	Muni Lagoon	937	3.4399	0.90671	0.02962
	Fosu Lagoon	833	3.4468	0.86385	0.02993
Supporting	Muni Lagoon	937	3.8147	0.94927	0.03101
	Fosu Lagoon	833	3.8358	0.91789	0.03180
Recreation	Muni Lagoon	937	3.7922	0.94482	0.03087
	Fosu Lagoon	833	3.8027	0.90727	0.03144
Provisioning	Muni Lagoon	937	3.7403	0.89942	0.02938
	Fosu Lagoon	833	3.7631	0.87422	0.03029
ES	Muni Lagoon	937	3.6973	0.83732	0.02735
	Fosu Lagoon	833	3.7132	0.79783	0.02764

Source: Field data (2023)

For regulating service, the study revealed that the magnitude of the differences in delivery between the two lagoons (mean differences = -0.007, 95% CI: -0.09–0.08) is very small, as revealed by an eta squared statistic of 0.005. The case found for the supporting services identified that there is also no statistically significant difference (t (1768) = 0.43; p = 0.64) between the Fosu Lagoon (M = 3.8358; SD = 0.91789) and the Muni Lagoon (M = 3.8147; SD = 0.94927). The study further revealed a small effect size (eta squared = 0.03), representing the magnitude of the lack of significant difference between supporting service delivery by the Fosu and the Muni Lagoons (mean differences = 0.021, 95% CI: -0.108–0.07) for the case. A widely accepted convention is to classify effect sizes as small (d = 0.2), medium (d = 0.5) and large (d = 0.8) according to benchmarks proposed by Cohen (1990).

The independent samples t-test further established that no statistically significant differences exist between the Fosu Lagoon and the Muni Lagoon in terms of their delivery of recreation ES (t (1768) = 0.237; p = 0.81).A small effect size revealed by an eta squared statistic of 0.01 supports the case for no significant differences in recreation services delivery between the two lagoons (mean difference = -0.01, 95% CI: -0.097–0.08).

In *Table 3* are presented the independent differences in MEA ecosystem service delivery, showing no relationship between the variables.

When asked to name a service supplied by nature, most participants mentioned food. As direct products of ecosystems, we have access to fruits, vegetables, trees, fish, and cattle. A provisioning service is any benefit to people derived from nature. Other sorts of provisioning services, in addition to food, include drinking water, timber, wood fuel, natural gas, oils, plants that can be used to make garments and other materials, and therapeutic benefits.Considering the delivery of provisioning ecosystem services, the study identified that Fosu Lagoon (M = 3.7631; SD = 0.87422) delivers more provisioning services than Muni Lagoon (M = 3.7403; SD = 0.89942). Despite Fosu Lagoon exceeding Muni lagoon in provisioning, the study found no significant differences between the provisioning service delivery by the two lagoons (t (1768) = 0.539; p = 0.59). Supporting the lack of statistically significant differences between provisioning service delivery by the Fosu and Muni Lagoons, the study found a somewhat small effect size with an eta squared statistic of 0.05 (mean difference = 0.023, 95% CI: -0.106–0.06).

Having established that no statistically significant differences exist between the Fosu Lagoon and the Muni Lagoon for all the types of ecosystem services, the study used the composite of all the scales for the four types of ES to explore the difference in the overall delivery of ES between the two lagoons. Finding at (1768) = 0.409 with a p-value of 0.68, the study emphasises that no statistically significant difference exists between the Fosu Lagoon (3.7132, SD = 0.79783) and the Muni Lagoon (M = 3.6973; SD = 0.83732). As shown for the overall delivery of ecosystem

services, the Fosu Lagoon scored higher than the Muni Lagoon in terms of delivering ecosystem service.

Instead in *Table 4* are displayed displays the effect size of the independent samples difference between the two groups. This value determines the magnitude of the difference between the means of the two groups, which is used to establish the practical significance of the difference between the two groups.

Differences in ES Between the Fosu and Muni Lagoons Based on the Marine ES Assessment Tool (MESAT) Scale

In *Table 5* are illustrated the group statistics of ES and MESAT for Fosu and Muni Lagoons.

The findings, according to *Table 6*, revealed that no subscales for the MESAT ES violated the assumption of equality of variances. The Levene's test of equality of variances found for all the types of ES were not significant: provisioning services ($F = 1.102$; $p = 0.294$), cultural services ($F = 1.31$; $p = 0.253$), regulating and maintenance services ($F = 0.517$; $p = 0.472$) and the composite of MESAT ecosystem service subscales ($F = 0.971$; $p = 0.325$). Based on these, the values of t that corresponded with the equal variances assumed were used to establish the significant differences in ecosystem service delivery by the two lagoons.

The statistical difference in the delivery of provisioning services found no statistically significant differences ($t(1768) = 0.295$; $p = 0.768$) between the Fosu Lagoon ($M = 3.5816$; $SD = 0.81951$) and the Muni Lagoon ($M = 3.5698$; $SD = 0.86366$). The magnitude of the differences in provisioning service delivery between the two lagoons (mean differences = -0.01184, 95% CI: -0.09–0.06) was very small, as revealed by an eta squared statistic of 0.00.

Table 3 – Independent Differences in MEA Ecosystem Service Delivery

Service	Levene's test for equality of variances		T-test for equality of means				
	F	Sig.	T	Df	Sig.	MD	SED
Regulating	1.237	0.266	-0.163	1768	0.87	-0.007	0.042
Supporting	0.249	0.618	-0.473	1768	0.64	-0.021	0.044
Recreation	1.004	0.316	-0.237	1768	0.81	-0.01	0.044
Provision	0.313	0.576	-0.539	1768	0.59	-0.023	0.042
Ecosystem Service	0.752	0.386	-0.409	1768	0.68	-0.016	0.039

MD = Mean Difference; SED = Standard Error Difference

Table 4 – Effect Size of Independent Samples Difference

Service	Eta squared	Effect Size
Regulating	0.005	Small
Supporting	0.038	Small
Recreation	0.0099	Small
Provisioning	0.05	Small
ES	0.029	Small

Source: Field data (2023)

Table 5 – Group statistics of MEA and ES Scales

	Lagoon	Mean	Std. D	SEM
Provisioning service	Muni Lagoon	3.5698	0.86366	0.02821
	Fosu Lagoon	3.5816	0.81951	0.02839
Cultural service	Muni Lagoon	3.5773	0.84932	0.02775
	Fosu Lagoon	3.5932	0.80851	0.02801
Regulating and maintenance service	Muni Lagoon	3.8258	0.90392	0.02953
	Fosu Lagoon	3.8436	0.86952	0.03013
Ecosystem	Muni Lagoon	3.6576	0.83110	0.02715
	Fosu Lagoon	3.6728	0.78890	0.02733

Source: Field data (2023)

Table 6 – Independent Differences in MESAT Ecosystem Service Delivery

Service	Levene's test for equality of variances		T-test for equality of means				
	F	Sig.	T	Df	Sig.	MD	SED
Provisioning	1.102	0.294	-0.295	1768	0.768	-0.01184	0.04015
Cultural	1.310	0.253	-0.402	1768	0.688	-0.01589	0.03954
Regulating and maintenance	0.517	0.472	-0.420	1768	0.674	-0.01776	0.04228
Ecosystem	0.971	0.325	-0.392	1768	0.695	-0.01516	0.03864

MD = Mean Difference; SED = Standard Error Difference

The study identified that there is also no statistically significant difference (t (1768) = 0.402; p = 0.688) between the Fosu Lagoon (M = 3.5932; SD = 0.80851) and the Muni Lagoon (M = 3.5773; SD = 0.84932) in terms of their delivery of cultural ecosystem services. The study further revealed a small effect size (eta squared = 0.00), representing the magnitude of the lack of a significant difference between supporting service delivery by the Fosu and the Muni Lagoons (mean differences = 0. 0158, 95% CI: -0.09344–0.06167).

The independent samples t-test also established that no statistically significant difference exists between the Fosu (M = 3.8436; SD = 0.86952) and Muni Lagoons (M = 3.8258; SD = 0.9039) in terms of their delivery of regulating and maintenance ES (t (1768) = 0.42; p = 0.674). A small effect size revealed by an eta squared statistic of 0.00 supports the case for no significant differences in recreation services delivery between the two lagoons (mean difference = -0.01776, 95% CI: -0.10–0.065). No statistically significant difference exists between the Fosu (M = 3.6728; SD = 0.78890) and Muni Lagoons (M = 3.6576; SD = 0.83110) in terms of their delivery of recreation ES (t (1768) = 0.392; p = 0.695). A small effect size revealed by an eta squared statistic of 0.00 supports the case for no significant differences in recreation services delivery between the two lagoons (mean difference = -0.015, 95% CI: -0.0909–0.0606).

DISCUSSION

The study found that 65.3% of respondents were male, while only 34.69% were female, indicating a gender imbalance in the survey. Respondents with primary school education were the most represented, accounting for about

37.4% of the total, with a monthly household income of 500 Ghana cedis. Half of the respondents lived in households with less than five people. The study revealed that the two lagoons were subjected to increasing urban exploitation, such as expansion into the catchment areas, over the past decades, with a recorded population increase in the areas under study. The annual population growth rate in Winneba, where the Muni Lagoon is found, is 2.2%, while that of Cape Coast Metropolis stands at 1.0%.

The population increase in the catchment areas, coupled with urbanisation and other related factors, poses a threat to the lagoons' abilities to provide their ecosystem services.

Difference in ES Between the Fosu and Muni Lagoons based on the Millennium Ecosystem Assessment (MEA) Scale

The Fosu and Muni Lagoons are two different ecosystems located in different geographical areas. They offer a fascinating opportunity to explore subtle differences in ecosystem services. Analysing these ecosystems using the comprehensive framework of the Millennium Ecosystem Assessment provides valuable insights into their ecological significance. Based on the findings that there are no statistical differences between the Fosu and Muni Lagoons, we accept the null hypothesis for both ecosystem service scales. This confirms that the Fosu and Muni Lagoons are similar in their deliveries of ecosystem services. The results also reveal that regulating services include procedures that manage natural phenomena such as pollination, water purification, erosion control and climate regulation. The study conducted by Huynh *et al.* (2022) found that lagoons play a crucial role in regulating various environmental services such as climate control, disease management, water purification, flood control and pollination. The study also revealed that socio-ecological systems are reflected in the way they interact with nature and humans, as outlined by Ostrom (2009) and McGinnis and Ostrom (2014). Thus, the study has shown that to fully incorporate networks, connectivity, dynamic landscapes and movement into the ES framework, it is necessary to adopt a socio-ecological viewpoint. This is because both social and environmental factors play a role in determining which ES are available to whom and to what degree. Socioecological systems demonstrate the close interdependence between human societies and ecosystems. The resilience of such systems hinges on a variety of factors, among them the connections between human societies and ecosystems. When we consider the socio-ecological connectivity of ES across a network, we gain a deeper understanding of how landscape-scale networks can bolster human wellbeing and ecological resilience, for example, by increasing resistance to regime shifts. This framework underscores the importance of harmonising natural, technological and socio-economic systems in the planning, design and management of urban nature-based solutions to achieve optimal socio-ecological outcomes. The analysis further revealed that there were no significant differences in the regulating services offered by the Fosu

and Muni Lagoons, indicating that both lagoons are equally effective in supplying the local community with services such as water filtration and climate control.

According to the research conducted by D'Alpaos and D'Alpaos (2021), coastal lagoon ecosystems contribute to a sense of place, improve biodiversity, support commercial fisheries, shield coastal areas from storms and erosion, generate income from ecotourism and function as effective natural carbon sinks that help counteract CO2 emissions and combat climate change. A healthy ecosystem can efficiently filter impurities from water and regulate climate, indicating balanced biodiversity and functioning natural processes (Okyere *et al.*, 2023). The study conducted by Huynh *et al.* (2022) found that lagoons play a crucial role in regulating various environmental services such as climate control, disease management, water purification, flood control and pollination. The study also revealed that the socio-ecological systems are reflected in the way they interact with nature and humans, as outlined by Ostrom (2009) and McGinnis and Ostrom (2014).

The analysis further revealed that there were no significant differences in the regulating services offered by the Fosu and Muni Lagoons, indicating that both lagoons are equally effective in supplying the local community with services such as water filtration and climate control. According to the research conducted by D'Alpaos and D'Alpaos (2021), coastal lagoon ecosystems contribute to a sense of place, improve biodiversity, support commercial fisheries, shield coastal areas from storms and erosion, generate income from ecotourism and function as effective natural carbon sinks that help counteract CO_2 emissions and combat climate change. A healthy ecosystem can efficiently filter impurities from water and regulate climate, indicating balanced biodiversity and functioning natural processes (Okyere *et al.*, 2023). According to the study, there were no noticeable variations in the supporting services of the lagoons. This implies that both lagoons have a comparable capacity to sustain plant and animal life and contribute to nutrient cycling and soil formation. These fundamental ecosystem functions are crucial for the creation of other ecosystem services, including primary production and nutrient cycling (Darkwa and Smardon, 2010). The study also revealed that the recreational services offered by the Fosu and Muni Lagoons were similar, indicating that both lagoons provide comparable leisure options for locals and tourists.

Recreational services refer to the benefits people derive from leisure activities such as fishing, boating and bird watching. The two lagoons, Fosu Lagoon in Cape Coast and the Aboakyer Festival of the Effutu people and Fetu Afahye of the people of Cape Coast, play significant roles in customary and traditional rites performed during festive periods. These waterbodies have cultural significances and offer opportunities for recreation and tourism. According to Aloba *et al.* (2022), Fosu Lagoon in Cape Coast, Ghana, is a Ramsar site that provides various services to the communities in and around the catchment area. These services include fishing, agricultural activities, hunting

expeditions and breeding. Conservation efforts and planning techniques can be streamlined since both lagoons provide similar environmental services.

Conservation initiatives for coastal lagoons are crucial for ensuring the sustainable use of ecosystem services. Policymakers and environmentalists can leverage this knowledge to implement comparable conservation programs in both regions without favouring one lagoon over the other. Resource managers can focus on applying the same techniques in both lagoons, such as taking measures to prevent pollution, managing fisheries responsibly and preserving ecosystems. The understanding that both lagoons offer similar ecological benefits allows for the creation of unified management methods. This is due to similarities in hydrodynamics, physical-chemical and biological properties, socio-economic dynamics and practically identical human activities that explore the services of the lagoons. Standardising conservation efforts and planning techniques between the two lagoons is possible and necessary to ensure the sustainable use of ES (Inácio *et al.*, 2019). Local authorities can promote the Fosu and Muni Lagoons as attractive recreational destinations without worrying about significant differences in the recreational experiences they offer. This could help encourage environmentally friendly leisure activities in the area. The fact that both lagoons have similar regulating systems suggests that they may react similarly to the effects of climate change.

As climate change can have significant implications for the wellbeing and livelihood of lagoon fishing communities (Davies-Vollum *et al.*, 2021), conservation and adaptation methods may be created to make both ecosystems resilient to changing environmental conditions. The similarities in ecosystem service delivery across both lagoons indicate the importance of coordinated efforts in conservation, resource management and climate change resilience measures. This understanding supports collaboration among stakeholders, ensuring the survival of these vital coastal ecosystems while streamlining decision-making processes. Taking a unified approach guarantees that the entire ecosystem is considered, eliminating fragmented actions that might impact other ecosystem components. This is essential for the ecosystem's general health (Essel *et al.*, 2019).

Difference in ES Between the Fosu and Muni Lagoons Based on the Marine ES Assessment Tool (MESAT) Scale

This study aims to investigate the differences in ES between the Fosu and Muni Lagoons using the MESAT scale. The researcher intends to shed light on the unique ecological dynamics of these lagoons, as well as the extent to which humans rely on them. By doing this comparative research, the aim is to develop sustainable conservation and management methods that cater to the specific requirements of each lagoon. Through advancing knowledge of lagoon ecosystems, the study highlights the importance of maintaining their benefits for the environment (Adu-Boahen, 2020).

For each type of ecosystem service, Levene's test was performed to determine if the assumption of equal variances across groups was violated. The result of Levene's test ($F = 1.102$; $p = 0.294$) indicates that there is no significant difference in the variances of provisioning services between the two lagoons. Similarly, Levene's test ($F = 1.31$; $p = 0.253$) shows that there is no significant difference in variances for cultural services. Additionally, for regulating and maintenance services, Levene's test ($F = 0.517$; $p = 0.472$) suggests that the variances are equal. Lastly, for the composite of all ecosystem service subscales, Levene's test ($F = 0.971$; $p = 0.325$) shows that there is no significant difference in variances. The two lagoons are providing similar ecosystem services, as shown by the absence of significant differences in variances across multiple categories. This indicates that the ecological processes in both lagoons are stable and in balance.

This data analysis examines the interplay of four ecosystem services, supporting, regulation, recreation or cultural and provisioning, in two coastal lagoons. It considers both the social and ecological factors that contribute to the provisioning of urban ESand the resulting positive impacts on humans. These benefits have been sustained over several decades. For example, cultural services involve social systems such as access, stewardship, maintenance, sense of place, public awareness and promotion. Ecologically, cultural services provide open space and coastal vegetation in the lagoons. Similarly, other services such as regulation and support are also provided. This study applies socio-ecological systems to link human and environmental factors.

Policymakers and ecosystem managers can use these results to make informed decisions on the allocation of resources and conservation efforts (Rodrigues-Filho *et al.*, 2023). If there were significant differences in variations, it might suggest an imbalance in the delivery of ecosystem services, requiring specific actions. However, the available data indicate a relatively consistent delivery of services. Schernewski *et al.* (2019) used the MESAT scale to evaluate two systems in the German Baltic Sea region: the rural Schlei and the urban/industrialised Warnow Estuary. By conducting data-based evaluations, they were able to demonstrate how the provisioning of ES has changed from the pre-industrial era in 1880 to the present day.

To summarise, the confirmation of equal variances in ES across the two lagoons strengthens the validity of any subsequent analyses. It also suggests that both lagoons are relatively balanced in their delivery of ecosystem services, which is encouraging conservation efforts and long-term sustainability planning.

Group Statistics of MEA ES Scales

Based on research, there appears to be no significant difference in the quality of provisioning services between Fosu Lagoon and Muni Lagoon. This means that both lagoons offer similar levels of provisioning services, as per the data collected and analysed. Even if there are minor numerical differences, they are not practically significant, given the extremely small mean difference and the condensed confidence interval.

Thus, the variation in the delivery of provisioning services between the two lagoons is insignificant in the real world and is unlikely to affect the choices or actions related to these services. Policymakers and lagoon managers can use this information to plan resource allocation or conservation efforts. If there are no significant differences in provisioning services, resources can be distributed evenly across both lagoons without favouring one over the other regarding provisioning services.

Independent Differences in MESAT Ecosystem Service Delivery

There was no significant difference in the provisioning services provided by the Fosu and Muni Lagoons. Provisioning services refer to resources like fish, shellfish and plants that are taken directly from the ecosystem. The fact that there is no discernible difference between the two lagoons suggests that both produce these resources at similar rates. This is likely the reason why there are laws, guidelines and community engagement efforts aimed at protecting ecosystems and ensuring that natural resources are used sustainably so that the lagoons can continue to provide these resources. According to Zaldívar-Jiménez *et al.* (2017), local participation in conservation initiatives can support sustainable resource management.

The research shows no discernible difference between the two lagoons in terms of cultural services. The non-material advantages that individuals derive from ecosystems, such as spiritual uplift and cultural legacy, are referred to as cultural services (Vasiljevic and Gavrilovic, 2019).

It was found that there is no significant difference between the two lagoons, indicating that both have equal cultural significance to the local populations. This suggests that both lagoons have similar cultural customs, traditions or historical importance associated with them. Additionally, it was found that services such as regulating and maintenance, which include water purification and climate regulation, were not significantly different either. This implies that both lagoons are equally important in maintaining environmental balance and providing essential services for the overall health of the ecosystem. This consistency is crucial for the sustainability of both areas and the organisms living within them.

The study also discovered that there is no significant difference in recreation services between the two lagoons. Recreation services include the benefits people obtain from recreational activities such as bird watching or boating. The lagoon environment is home to a diverse range of species, including birds, reptiles, fish, mammals, amphibians and invertebrates (Maxwell, 2019).

Both the Fosu and Muni Lagoons offer similar leisure activities. The study reveals that there are no significant differences in ES between the two lagoons. This has implications for environmental managers and policymakers who can use this data to make informed decisions about resource management and conservation efforts. As the functions provided by both lagoons are equivalent, it is possible to develop conservation strategies that apply to both locations.

This information can also benefit the communities living close to these lagoons, helping them make sustainable resource use decisions. If there were any notable disparities, each lagoon would require a different strategy. However, since the services provided by the lagoons are similar, community activities and policies could be the same for both locations, ensuring fairness and equity in resource use.

CONCLUSIONS AND RECOMMENDATIONS

This paper compares the Fosu and Muni Lagoons, culturally sensitive habitats located in the coastal central plains of Ghana, in terms of their ecosystem functioning. This study aimed to shed light on the complex ecological dynamics of these lagoons by employing two scales of measurement: the MEA and the MESAT scales. The findings indicated that there were no statistically significant differences between the Fosu and Muni Lagoons. Therefore, the null hypothesis is accepted for both ecosystem service scales used, suggesting that the two coastal lagoons share many similarities in terms of their service delivery. These similarities in service delivery ensure unity of cultural worth and increase social ties and communal spirit, possibly encouraging cooperation in conservation and cultural preservation initiatives. It appears that there is not a significant difference between the two lagoons. This suggests that they hold equal cultural importance to the local populations. Similar cultural practices, traditions or historical significance may be associated with both lagoons. The fact that there are no noticeable differences in cultural services supports the idea that the communities surrounding the lagoons share rich common cultural heritages. This shared cultural value not only strengthens social bonds and solidarity but also provides a strong foundation for collaborative efforts in conservation and cultural preservation. Ultimately, this can greatly enhance the quality of life for the communities involved.

The study shows that there are variations in all ecosystem functions analysed. However, the Fosu and Muni Lagoons have similar ecosystem functions, indicating ecological equivalency. This means that both lagoons offer similar services, regardless of their location, size or environmental conditions. This knowledge is crucial for ensuring equitable and sustainable management strategies, which can be consistently applied to both lagoons. It promotes environmental justice by ensuring that both populations have equal opportunities to benefit from the ecological and socio-economic resilience of these lagoons. The study results indicate that there are no significant differences in the cultural services provided to the local communities surrounding the lagoons. It is important to involve and include these communities in conservation and cultural preservation initiatives. They must be given a voice in discussions and decision-making while respecting their customs, knowledge, and practices. To encourage sustainable development around the lagoons, the Traditional Council, the Environmental Protection Agency (EPA), the Ministry of Fisheries and Aquaculture Development and the Ministry of Environment, Science,

Technology and Innovation need to work together to create regulations. State and non-governmental institutions should collaborate with local communities to maintain the culturally significant coastal ecosystems. The programs should prioritise community wellbeing, ecological conservation and cultural preservation. Additionally, incentives should be provided to encourage eco-friendly measures and initiatives to preserve cultural heritage.

Policymakers should implement appropriate regulations to reduce environmental pressure caused by over-exploitation, as the lagoons are culturally significant. To ensure the sustainability of the management process, there is an opportunity to broaden the base of participants in decision-making processes regarding the lagoons and to improve stakeholder participation in their management.

This is important because although the respondents provided clear answers to the questions, some of them were not actually involved in the decision-making process for managing the lagoons and their services. Minimising potential conflicts and deterioration that may arise from the use of ES provided by the Muni and Fosu Lagoons is necessary to ensure their sustainability, emphasising the strengthening of community institutions.

The initial hypothesis suggested that there was a significant difference in the delivery of ES between Fosu Lagoon and Muni Lagoon. However, the comprehensive study has revealed otherwise. The researchers have pointed out that various factors could have influenced this outcome, including the unexpected similarity in ecological characteristics between the two lagoons. It is essential to acknowledge the value of this research, as it challenges existing assumptions.

The absence of a significant difference in ecosystem service delivery between these lagoons opens avenues for further exploration and challenges researchers in this field to refine their methodologies and re-evaluate preconceived notions about similar ecosystems.

Limitations and Suggestions for Future Studies

It was difficult to determine the target group for the research due to the ambiguous nature of the study. As a result, the overall population of people who were aware of the ES concept was unknown. To overcome this challenge, the convenience sampling method was employed, which involved using diverse sample seeds, reasonable persistence and different waves of sampling. This method is recommended by Kirchherr and Charles (2018) to enhance sample diversity when a sampling frame cannot be constructed. It also enables researchers to collect a wide range of perspectives on a subject or knowledge area that extends beyond organisations or institutions. However, a limitation of the study was the inability to conduct in-depth interviews with some key informants in the two study areas to gather qualitative data that would have supported the quantitative data used for the study. Despite this limitation, the findings provide valuable insights for the development of policies and practices related to the conservation and management of coastal resources. Further research is required to assess the

provision of ES in coastal lagoons by utilising a combination of mixed methods. To ensure a comprehensive analysis, the study must gather qualitative data through interviews and focus group discussions in addition to quantitative data. This will effectively incorporate the perspectives of all participants. Additionally, the authors may consider alternative methods of measuring ecosystem services, including employing varying scales.

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