Study of the local population's perceptions of the ecosystem services provided by mangroves in Benin

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Research

Abstract

Background: Mangrove ecosystems, which provide various ecosystem services (ES), face threats from both natural and anthropogenic sources. However, the relationship between ES and their direct beneficiaries, namely local communities, is often not obvious. This study analyzed the perceptions of the local population regarding the importance of different ES categories in the mangrove region of the Bouche du Roy Community Biodiversity Conservation Area (CBCA) in Benin.

Methods: Surveys were conducted with 41 residents, targeting diverse socioeconomic profiles including fishermen, salt producers and ecoguards. We compared the average importance ratings of 12 ES, including provisioning, regulating and cultural ES. Then, a multiple regression analysis and a post-survey debriefing report were used to identify differences in ES importance ratings by respondent profile.

Results: Mean scores for food provisioning (4.37), carbon sequestration (3.83), and erosion control (3.46) were the highest, while those for water purification (1.83) and medicinal services (1.85) were the lowest. Perceptions varied by profiles and genders, except for food provisioning, water resources, and erosion control, which showed no significant differences. Respondents with a sound knowledge of mangrove ES valued them highly, underscoring the tangible benefits and growing awareness of mangrove contributions fostered by conservation efforts.

Conclusions: The successful protection of CBCA mangrove ecosystems depends on social acceptance, which relies on their ability to provide livelihoods, climate and coastal regulation, as well as cultural, spiritual, and touristic values. Consultation with local communities can integrate their interests in protection plans.

Keywords: mangroves, ecosystem services, community consultation, Benin.

Resumé

Contexte : Les écosystèmes de mangroves, qui fournissent divers services écosystémiques (SE), sont menacés par des menaces d'origine naturelle et anthropique, nécessitant la mise en œuvre de politiques de protection. Cependant, la relation

entre les SE et leurs bénéficiaires directs, à savoir les communautés locales, n'est souvent pas évidente. L'objectif de cette étude était d'analyser les perceptions de la population locale concernant l'importance des différentes catégories de SE dans la région de mangroves de l'Aire communautaire de conservation de la biodiversité (ACCB) Bouche du Roy au Bénin.

Méthodes : Nous avons administré des questionnaires d'enquêtes à 41 répondants résidant autour de l'ACCB, ciblant divers profils socio-économiques, notamment des pêcheurs, des producteurs de sel ou des écogardes. Nous avons comparé les scores moyens d'importance de 12 services, y compris les SE d'approvisionnement, de régulation et culturels. Ensuite, une analyse de régression multiple et un bref entretien post-enquête ont permis d'identifier les différences dans les scores d'importance selon les profils des répondants.

Résultats : Les scores moyens pour l'approvisionnement alimentaire (4,37), la séquestration du carbone (3,83) et le contrôle de l'érosion (3,46) étaient les plus élevés, tandis que ceux pour la purification de l'eau (1,83) et les services médicaux (1,85) étaient les plus bas. L'analyse statistique a également révélé des variations dans les perceptions des valeurs ES selon les différents profils et sexes des répondants, à l'exception de l'approvisionnement alimentaire, des ressources en eau et du contrôle de l'érosion, qui n'ont montré aucune différence significative. Les personnes interrogées ayant une bonne connaissance des SE des mangroves les ont hautement appréciées, soulignant les avantages tangibles et la prise de conscience croissante des contributions des mangroves favorisées par les efforts de conservation.

Conclusions : La protection réussie des écosystèmes de mangroves de l'ACCB dépend de l'acceptation sociale, qui repose sur leur capacité à fournir des moyens de subsistance, une régulation climatique et côtière, ainsi que des valeurs culturelles, spirituelles et touristiques. La consultation des communautés locales peut intégrer leurs intérêts dans les plans de protection.

Mots-clés : mangroves, services écosystémiques, consultation communautaire, Bénin

Background

The emergence of the ecosystem services (ES) concept, defined as the set of benefits that humans derive from ecosystems, reflects humanity's increasing awareness of the overexploitation of natural resources and the necessity for their protection, restoration, or sustainable management (Méral 2012; MEA 2005). Although this awareness is fueling the integration of ES into decision-making processes, the ES concept faces various uncertainties and criticisms (Barnaud *et al.* 2011; Dupras 2014). Besides the scientific uncertainties regarding the dynamics underlying the production of ES, Barnaud *et al.* (2011) highlight societal uncertainties surrounding the ES concept, particularly the existence of multiple perceptions regarding ecosystem services. Moreover, their assessment, especially in monetary terms, often provokes skepticism due to the potential commodification of nature's goods and services that ensues (Arnauld de Sartre *et al.* 2014; Gómez-Baggethun 2015).

Likewise, the use of the ES concept in conservation strategies and the establishment of protected areas raises several questions, particularly regarding consultation with the local population, with whom and often for whom protective measures are implemented (Diedhiou *et al.* 2021; Kaboré *et al.* 2014). Indeed, while conservation and management measures are necessary for ecosystem preservation on one hand, it is equally crucial to consider the knowledge, practices, and benefits that the local population derives from these ecosystems, as well as the importance they attribute to them (Yildirim *et al.* 2017). This would enable a more coherent and fairer framework for decision-making. Consequently, our understanding of the ES produced by mangrove ecosystems, which serve as a pivotal link between marine and terrestrial systems, would benefit from a study that addresses various analytical angles (Barbier 2016).

Mangrove ecosystems are forest formations found in tropical coastlines, are mainly composed of mangrove trees, and play a crucial role as habitats for a rich and diverse biodiversity (Savari *et al.* 2022; Teka *et al.* 2018). They also perform crucial functions such as coastal protection, carbon dioxide (CO2) sequestration, water filtration, and control of coastal erosion (Ajonina *et al.* 2014; Balla Dieye *et al.* 2013; Ndour *et al.* 2012). Mangrove ecosystems are often vital fishing grounds, providing an important source of food and income for local populations (Ashton 2010; Diedhiou *et al.* 2021; FAO 2009). Additionally, they are used for recreational, touristic, and cultural purposes. However, despite their importance, these ecosystems are subject to various pressures, including economic pressures such as urbanization, agricultural development, shrimp aquaculture, and environmental pressures such as temperature variations and decreased precipitation (Arumugam *et al.* 2020; Ashton 2010; Teka *et al.* 2018; Vande Velde *et al.* 2019). Moreover, weak regulatory frameworks or limited perception of risks or benefits in political contexts can impact their conservation (Savari *et al.* 2022). These pressures threaten mangrove ecosystems in several regions of the world, reducing their capacity to provide ecosystem services, thus justifying various mangrove protection initiatives (Vande Velde *et al.* 2019).

Ecosystem services (ES) are now central to various strategies for the protection and sustainable management of natural resources, particularly in biosphere reserves within the framework of the Man and Biosphere program of United Nations Educational, Scientific and Cultural Organization (Amadou 2008; Dudley 2008; Ngom *et al.* 2014). Biosphere reserves are a type of protected area that aims to safeguard and enhance the sustainability of ecosystems while promoting the economic and social development of local communities (Bruner *et al.* 2001; Saleh 2012; Yildirim *et al.* 2017). It is within this framework that our study focuses on the various ES provided by mangroves. Our research was conducted in the Bouche du Roy Community Biodiversity Conservation Area (CBCA), primarily composed of mangroves, and located in the Mono Biosphere Reserve in Benin. We analyzed the local population's perception of the importance of the various ES provided by mangroves, through a survey and a post-survey debriefing. We aimed to further inform decisions and conservation strategies for these ecosystems while encouraging the participation of local communities in discussions regarding the management of their territory.

Materials and Methods

Study environment and context

The Bouche du Roy CBCA is a coastal wetland characterized by the presence of mangroves extending between terrestrial ecosystems, freshwater, and marine environments (Ndour *et al.* 2012; Sinsin *et al.* 2018). It is an estuary fed by the Mono River and the Ahémé lake surrounding the villages of the CBCA (see Figure 1), mainly inhabited by *Idhôdatôlè* or *Todjisonto* (fishermen, in the local language, Xweda and Xwla). The principal economic activity in this region is artisanal fishing, both in fresh and marine waters, followed by salt production and exploitation of the rushes (*Typha australis*). Agriculture, fish farming, market gardening, and local product processing activities are also present as secondary activities (Kikpa Bio & Dupras 2023). Additionally, the CBCA is a tourist destination offering various biodiversity-focused activities, such as mangrove tours, whale watching, and birdwatching sites. The region also hosts remarkable historical and natural sites, such as the estuary, the royal city of Ouidah, and the site of the Door of No Return, symbolically linked to the history of the transatlantic slave trade. Socio-cultural activities such as red oil processing, salt production, and cultural and spiritual events also enrich the region's tourism industry. Thus, most of the CBCA inhabitants depends on mangrove ecosystems for their economic survival.

The process of creating and managing the CBCA involves interaction among five main types of actors: the local association Doukpo, NGOs, municipalities, state structures, and technical and financial partners. In addition to using protection strategies such as reforestation and mangrove maintenance, management institutions also resort to socio-cultural and spiritual arrangements for protection, by sanctifying certain areas and entrusting them to the protection of deities to preserve these ecosystems. An analysis of the institutional interactions within the CBCA reveals an institutional bricolage in management, highlighting the agreements and understandings reached between the various stakeholders, as well as the hybridization of biodiversity conservation strategies (Kikpa Bio & Dupras 2023).

The sustainable management of the CBCA supports the local economy, even if restrictive conservation objectives may appear constraining (Kikpa Bio *et al*. 2025). In this context, it is essential to understand the importance that the local population attributes to different ES to inform and optimise the CBCA's conservation and management strategies. Specifically, the status of the CBCA as a community protected area of category VI and a biosphere reserve site offers opportunities for sustainable extraction and use of natural resources (PAGS 2017; Woodley 2008).

Research activities and data collection

Data were collected using a survey questionnaire and a post-survey debriefing in which respondents were asked a series of questions that prompted them to explain their survey responses. Surveys facilitate the quantification of responses, as well as multivariate analyses (Berthier 2010; Javeau 1990; Marquet *et al.* 2022). The process was inspired by other studies on populations perceptions of ES (Badiane *et al.* 2019; Diedhiou *et al.* 2021; Ngom *et al.* 2014; Ouedraogo *et al.* 2020). Specifically, the study relied on the knowledge and prioritization of the importance of ES (Aubin *et al.* 2014; Yildirim *et al.* 2017), focusing on the values that the population attributes to mangrove ES. Research activities and data collection occurred in three stages.

Firstly, an exploratory field phase in Benin took place from May to July 2018. Exploratory surveys and the collection of primary documents related to the creation and planning of the biosphere reserve, particularly the Bouche de Roy site, highlighted the main ES of the territory as well as socio-economic activities. Secondly, through a literature review on mangrove ecosystems (Barbier 2016; Bojang 2009; Brander *et al.* 2012; Giry *et al.* 2017) and based on the examination of exercises in the classification of ES (e.g., MEA (2005), CICES (2018), IPBES (2019)), we selected the main relevant ES for the

study site. In the second stage of the research, we validated the list of ES through exploratory surveys with the five main stakeholder groups. We then retained the mangrove ES that these groups identified as significant to community. In total, we identified four mangrove ES for each of the categories of provisioning, regulation, and cultural ecosystem services, as presented in Table 1. The third stage of the research involved collecting the perception survey data, and the follow-up debriefing. Data collection on the perception of local inhabitants of the CBCA Bouche du Roy regarding mangrove ecosystems involved 41 respondents, 29% of which were women and 71%, men, as shown in Table 2. Fishermen and fish smokers were the most represented group. Most of the surveys were conducted in the local languages Xla, Xweda, or Fon. None of the respondents were familiar with the concept of ecosystem services beforehand. However, all were well-informed about the numerous benefits of mangrove ecosystems. The perception survey questionnaire asked respondents to rate the twelve different mangrove ecosystem services listed in Table 1. An appreciation scale ranging from 1 to 5 was used, as follows: 1: very unimportant, 2: unimportant, 3: moderately important, 4: quite important, 5: very important. The surveys were exclusively addressed to people who had resided in the region for at least two years and were at least 18 years old. We explained the concept of ecosystem services to the respondents, who then assigned a value to each ES presented. We then conducted brief interviews, asking respondents to explain the reasons for their survey responses in relation to the values assigned to each ES.

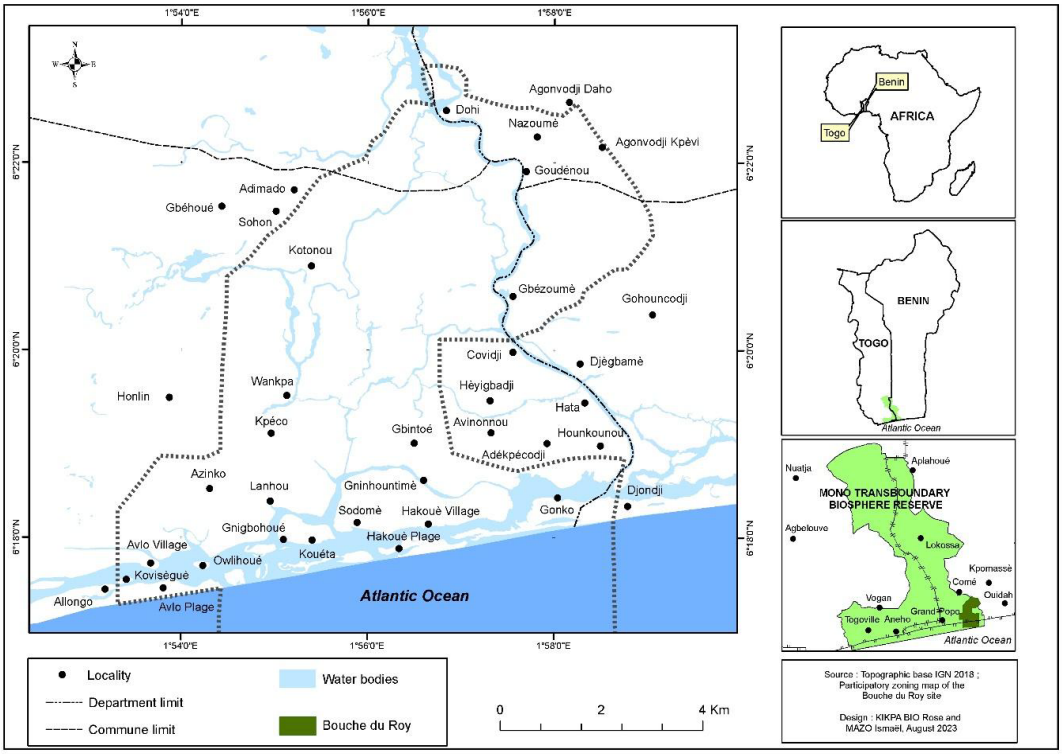

Figure 1. Map of the geographical location of the Bouche du Roy CBCA

Table 1. List of selected CBCA Ecosystem Services

Category	Ecosystem services	Description
Provisioning services	Heating and construction materials	Firewood, wood, or rush (Typha australis) for construction and craftwork charcoal
	Food	Fish, oysters and crabs, animals, birds, salt
	Water resources	Agricultural and domestic uses
	Medicinal resources	Mangrove propagules, leaves, fruit, and barks for pharmacopoeia
Regulating services	Carbon sequestration	CO2 emissions absorption, natural carbon sinks, CO2 storage (aerial and oceanic)
	Erosion control	Soil erosion, particle transport and deforestation reduction; maintenance of flora and fauna
	Flood control	Waves attenuation; protection against flooding
	Water purification	Surface water and groundwater purification
Cultural services	Spiritual and religious activities	Sites of worship and religious sites

Tourism	National and international
Education	Research, educational outings and school activities
Cultural heritage	Cultural and heritage significance

Surveys were conducted in the 17 villages and hamlets of the CBCA from February to June 2020, with approximately 2 to 3 respondents per village. Respondents were selected using non-probabilistic sampling, using the reasoned choice technique which involves intentionally selecting key respondents (Beaud 2009; Marquet *et al.* 2022), to ensure a diversity of perspectives and uses of ecosystems. Thus, the respondents in this study represent various profiles (characteristics) in the local community, including village chiefs, members of the local association called Doukpo, eco-guards and local guides, fishermen, salt producers, women from associations engaged in income-generating activities (IGA), farmers, and market gardeners. Some respondents have profiles that fit more than one of these characteristics. Table 2 presents the main characteristic identifying the respondents, by gender.

The data analysis was conducted using the *Stata software*. Analyses of means and standard deviations of ES highlight the importance and variation of values for each ES (Saporta 2006). Subsequently, statistical tests were performed to examine the hypothesis that there is a relationship between respondent characteristics (gender and/or profile) and the importance attributed to mangrove ES, as well as the influence of the value attributed among different types of ES themselves. To that effect, several multiple linear regression (MLR) analyses were estimated to test whether respondents with certain profiles or gender had lower or higher values for the various ES than respondents with other profiles or gender. These statistical tests provide enriching and significant information for evaluating the importance of mangrove ES, as well as the relationships between them and the different profile of respondents studied.

Table 2. Characteristics of survey respondents by gender

Characteristics of respondents	**Number**		
	Men	**Women**	**Total**
Village chiefs	8	0	8
Doukpo members	4	1	5
Ecoguards and local guides	5	0	5
Fishermen and fish smokers	10	3	13
Salt producers	1	3	4
Women's associations and IGAs	0	4	4
Farmers and market gardeners	1	1	2
Total	29	12	41

Results

This section presents the results obtained for the ES importance values. We estimated mean values and standard deviations and performed statistical tests using multiple linear regression. The ranking of the twelve ecosystem services sparked discussions in follow-up interviews on factors influencing the attribution of value to a given ES, the various benefits of mangroves, and the impact of the creation of the CBCA. The discussion that follows relies on both the survey and the post-survey interview results.

Importance of mangrove ES

Table 3 presents the survey means, their standard deviation, standard errors, and 90% confidence intervals (CI) for the 12 ES. The standard deviation (SD) is a measure of the variability in responses. The standard error (SE) is a measure of the accuracy of the sample mean as a reflection of the population mean and can be used to conduct statistical tests. However, an underlying assumption for this use is that the sample is representative of the underlying population, typically a random sample. While our purposive sample was not randomly chosen, we believe that it is representative of the underlying population. We therefore conducted *t*-tests to find out whether the differences in ES importance means between groups were significant. The 1-tailed *t*-test column indicates whether the null hypothesis (Ho) that the ES means are equal against the alternative (Ha) that the ES with the lower mean is statistically different from the ES with the higher mean for those ES with CI overlaps (no overlap indicates that the alternative (Ha: X<Y is accepted). For example, we can see that there is no overlap in the CIs for food and carbon sequestration at the 90% confidence level, and thus conclude that the mean for carbon sequestration is lower than the mean for food. On the other hand, there is an overlap between the CIs for heating and construction materials and erosion control, and we cannot therefore conclude that former is higher than the latter based on their CIs and therefore conducted the test.

Table 3. Table 3: ES importance to CBCA Bouche du Roy residents

Ecosystem service (ES)	ES type	Rank	Mean	Standard deviation	Standard error	Confidence interval (90%)		1-tailed t-tests of means (90%)
Food	Provisioning	1	4.37	0.58	0.09	4.21	4.52	No overlap with previous CI
Carbon sequestration	Regulating	2	3.83	0.59	0.09	3.67	3.98	No overlap with previous CI
Erosion control	Regulating	3	3.46	0.59	0.09	3.31	3.62	No overlap with previous CI
Heating and construction materials	Provisioning	4	3.39	0.80	0.13	3.18	3.60	Ho: 4=3, not rejected
Cultural heritage	Cultural	5	3.27	0.59	0.09	3.11	3.42	Ho: 5=4, not rejected; Ha: 5<3
Tourism	Cultural	6	3.07	0.96	0.15	2.82	3.33	Ho: 6=5, not rejected; Ha: 6<4; Ha: 6<3
Spiritual and religious activities	Cultural	7	3.05	0.67	0.10	2.87	3.22	Ho: 7=6, not rejected; Ha: 7<5; Ha: 7<4
Flood control	Regulating	8	2.56	0.70	0.11	2.37	2.75	No overlap with previous CI
Education	Cultural	9	2.37	0.54	0.08	2.22	2.51	Ha: 9<8
Water ressources	Provisioning	10	2.12	0.51	0.08	1.99	2.26	Ha: 10<9
Medicinal resources	Provisioning	11	1.85	0.69	0.11	1.67	2.04	Ha: 11<10
Water purification	Regulating	12	1.83	0.70	0.11	1.64	2.01	Ho: 12=11, not rejected; Ha: 12<10

Legend: CI = confidence intervals, Ha = hypothesis alternative, Ho = hypothesis

The results reveal that the provisioning of food is the most important ecosystem service for respondents, with an average rating of 4.37. Additionally, carbon sequestration, erosion control, heating and construction materials, cultural heritage, tourism, and spiritual aspects all received average importance ratings above 3, indicating that they are all perceived as having at least moderate importance. The lower values indicate a limited importance to respondents for certain mangroves ES, notably flood mitigation, educational services, water resources, medicinal services, and water purification. The ES importance standard deviations range between 0.51 and 0.96, indicating a relatively low dispersion of the importance attributed to the various ES by respondents. The highest standard deviations were observed for heating and construction materials (0.80) and tourism (0.96), indicating a higher diversity of perceptions among respondents for these ES. Heating and construction materials include firewood, wood, and rushes for construction or craftsmanship. The higher standard deviation may be explained by the fact that certain respondents value rushes for personal or commercial purposes while other would prefer to see a lower use of mangrove wood in accordance with conservation measures. As for the tourism ecosystem service, the higher standard deviation may be explained by the fact that tourism activity in the area benefits only a small portion of the population, notably guides, restaurateurs, or traders. For the remainder of services, standard deviations fluctuate between 0.50 and 0.70.

Importance of provisioning services

Provisioning services intended for consumption or sale are tangibles whose benefits are easily grasped, making their evaluation easier for respondents. Table 3 demonstrates that the ratings obtained by the four provisioning supply services are statistically different. In this regard, the contribution of mangrove ecosystems to food provisioning holds a prominent place, obtaining a value of 4.37 out of 5 according to participant responses (see Figure 2). During the post-survey interviews the most frequently mentioned food obtained included fish, oysters, salt, and other crustaceans and mollusks. Additionally, heating and construction materials (3.39) which include firewood, wood, and rushes for construction or craftsmanship hold moderate importance for respondents. In this regard, while conservation measures in the community area have led to a reduction in wood use and cutting, the exploitation of rushes, an herbaceous plant, is beginning to gain momentum in the region with the development and support of women's associations that exploit this plant. Water resources (2.12) offer relatively limited benefits, although they are essential to support other ecosystem services. According to interviewed respondents, the salty nature of the water resource from mangrove ecosystems in the area, as an estuary, limits its direct use for consumption. The region also appears to be facing a shortage of drinking water. Mangroves, particularly mangrove propagules, are also used in traditional medicine for the treatment of various skin and oral conditions. The low value attributed to medicinal services (1.85) could be linked to a decrease in their use by respondents, in favor of medical and pharmaceutical treatments.

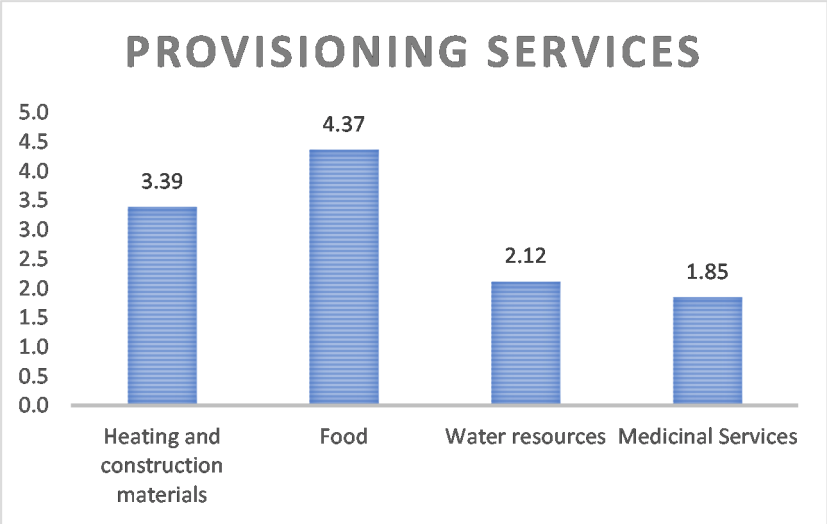

Figure 2. The average importance of provisioning services

Importance of regulating services

The intangible nature of ecosystem regulation services can complicate their evaluation for the public. However, the results reveal that the population has a good understanding of the importance and contribution of mangrove ecosystems to climate regulation (see Figure 3). Table 3 also demonstrates that the ratings obtained by the four regulating services are statistically different. This understanding can be attributed to various awareness campaigns conducted during the creation of the

protected area, according to the respondents. For example, during data collection we observed information panels on the utility of mangroves in the villages of the study area, which likely contributed to respondents' better understanding of the importance of these ecosystems for providing regulating services. Thus, respondents considered carbon sequestration (3.83) and erosion control (3.46) relatively important. In contrast, flood mitigation (2.56) and water purification (1.82) services garnered lower importance scores. According to respondents, despite the presence of mangroves, the area is wet and often flooded. Similarly, the importance of mangroves for water purification is perceived as low by respondents, who referred in interviews to the abundance of dead mangrove leaves and their tendency to clutter the water, which could explain the low score for these services.

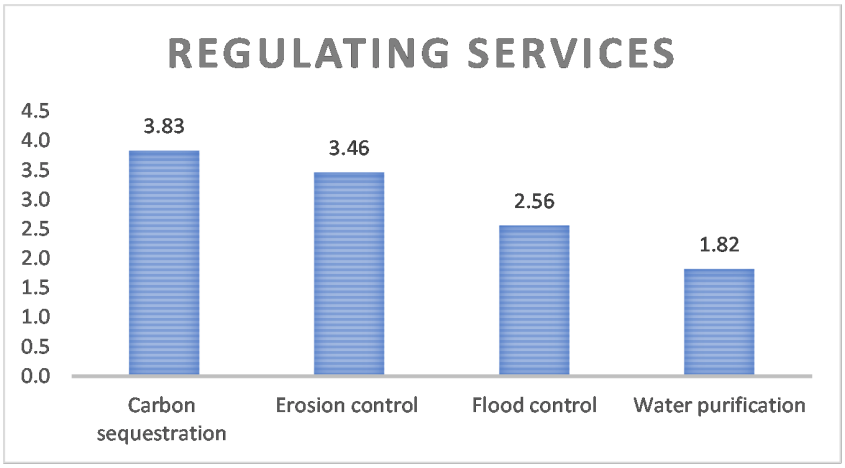

Figure 3. The average importance of regulating services

Importance of cultural services

For cultural ecosystem services, cultural heritage, which scored 3.27, is considered the most important (see Figure 4). This may be explained by the predominant profile of the inhabitants, mainly fishermen. Indeed, according to the respondents the area's inhabitants attach great importance to mangrove ecosystems as an integral part of their heritage. There is a cultural and historical relationship between mangroves and the inhabitants of the area, with the latter settling inside mangrove formations to protect themselves from tribal wars. Spiritual and religious activities (3.05) and tourism (3.07) received slightly lower importance scores. Indeed, as indicated in Table 3, the tourism score is not statistically different from the cultural heritage score, and the spiritual and religious activities score is not statistically different from the tourism score. Local tourism activities highlight spiritual beliefs and places of worship located within ecosystems, thereby contributing to their protection. However, despite the tourism potential of the area and the presence of biodiversity circuits, tourist numbers remain low, especially with Covid in 2020. Finally, the educational aspect, with a score of 2.36, garnered the lowest average score for cultural services. This is likely due to the limited development of research activities, educational outings, and school activities in the area.

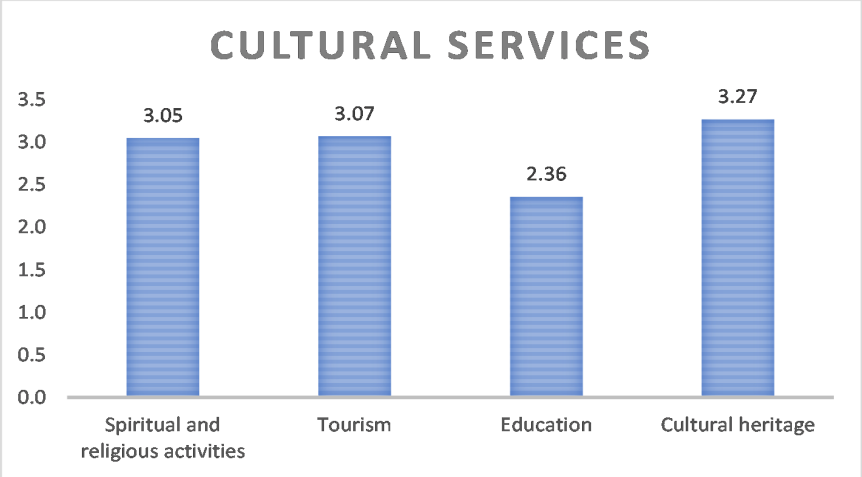

Figure 4. The average value of cultural services

Differences in the importance of ES by respondent characteristics

To refine our understanding of the relative importance of mangrove ES to the various population segments, we conducted multiple linear regression (MLR) analyses using respondent profiles as explanatory variables. We considered a threshold level of 5% then 10% to interpret results, given the small sample size. First, for each ES, we used fishermen as the base profile, as it is the profile with the largest number of respondents. Secondly, estimations using combinations of profiles were carried out by removing variables (profiles), if the original estimates for those variables were similar to those of fishermen, which meant that the (constant) base would now also includes these removed profiles. Certain profiles were also combined into one variable if their estimates were similar to each other, yet different from fishermen's estimates. Third, gender was added in the regressions to determine whether the gender variable estimate would be significant. The MLR results are reported in Appendix A. Note that the food, erosion control, and water resources are not included in the table as no significant coefficient estimates were found for these ES.

The MLRs revealed significant differences in the importance attributed to the remaining ES by the different respondent groups (profiles). Appendix A shows the different combinations of constant (base) made. Profiles with identical coefficients and *p*-values shown in the table were combined in the MLR. The regressions revealed that women rate the importance of spiritual and religious services more highly than men, but no other rating differences were identified for women for the remaining 11 ES. For the remainder of the discussion, we proceed by ES.

Heating and construction materials: fishers and fish smokers, Doukpo members, ecoguards and local guides and salt producers rated the importance of this ES at 3.59, while village chiefs, members of women's associations and IGAs, and farmers and market gardeners rated it at 3.00 (3.59 – 0.59). Farmers and gardeners, women belonging to associations or the IGA, and village chiefs rated the importance of heating and construction materials less than other groups.

Medicinal resources**:** fishers and fish smokers, Doukpo members, and farmers and market gardeners rated the importance of this ES at 2.00, while village chiefs rated it at 1.50 (2.00 – 0.50) and ecoguards and local guides, salt producers, and members of women's associations and IGAs at 1.86 (2.00 – 0.14). Village chiefs rated the importance of medicinal resources as less important than fishers, farmers and gardeners, and Doukpo members.

Carbon sequestration: fishers and fish smokers, village chiefs, Doukpo members, and salt producers rated the importance of this ES at 3.66, while ecoguards and local guides rated it at 4.34 (3.66 + 0.68), members of women's associations and IGAs at 4.00 (3.66 + 0.34) and farmers and market gardeners at 4.50 (3.66 + 0.84). Farmers and gardeners and ecoguards and local guides rated the importance of carbon sequestration more highly than fishers, village chiefs, Doukpo members, and salt producers.

Flood control**:** fishers and fish smokers, village chiefs, and farmers and market gardeners rated the importance of this ES at 2.45, while ecoguards and local guides rated it at 3.33 (2.45 + 0.88), salt producers at 2.75 (2.45 + 0.30), and Doukpo members and members of women's associations and IGAs at 2.22 (2.45 – 0.23). Ecoguards rated the importance of flood prevention more highly than all other groups except salt producers.

Water purification**:** fishers and fish smokers and village chiefs rated the importance of this ES at 1.75, while Doukpo members rated it at 1.20 (1.75 – 0.55), ecoguards and local guides rated it at 2.83 (1.75 + 1.08), salt producers at 2.00 (1.75 + 0.25), and members of women's associations and IGAs and farmers and market gardeners at 1.50 (1.75 – 0.25). Ecoguards rated the importance of water purification more highly than all the other groups, while members of the Doukpo rated it less highly than fishers, village chiefs, and salt producers.

Spiritual and religious activities: fishers and fish smokers rated the importance of this ES at 3.25, while village chiefs rated it at 2.37 (3.25 – 0.88), Doukpo members, ecoguards and local guides, and farmers and market gardeners rated it at 3.00 (3.25 – 0.25), salt producers and members of women's associations and IGAs at 3.50 (3.25 + 0.25). Village chiefs rated the importance of spiritual and religious ES less highly than all the other groups.

Tourism**:** fishers and fish smokers, village chiefs, and members of women's associations and IGAs rated the importance of this ES at 2.83, while Doukpo members and salt producers rated it at 3.22 (2.83 + 0.39), ecoguards and local guides rated it at 4.00 (2.83 + 1.17), and farmers and market gardeners rated it at 2.50 (2.83 – 0.33). Ecoguards rate the importance of tourism more highly than other groups except Doukpo members and salt producers, although the difference between the ecoguards ratings and those of Doukpo members and salt producers is almost statistically significant at the 10% level.

***Education*:** fishers and fish smokers, Doukpo members, members of women's associations and IGAs, and farmers and market gardeners rated the importance of this ES at 2.17, while village chiefs and salt producers rated it at 2.50 (2.17 + 0.33) and ecoguards and local guides at 2.83 (2.17 + 0.66). Ecoguards, village chiefs, and salt producers rated educational opportunities more highly than fishers, farmers and gardeners, women belonging to associations, and Doukpo members.

Cultural heritage: fishers and fish smokers, village chiefs, and salt producers rated the importance of this ES at 3.33, while Doukpo members rated it at 3.20 (3.33 – 0.17), ecoguards and local guides rated it at 2.83 (3.33 – 0.50), members of women's associations and IGAs and farmers and market gardeners at 3.50 (3.33 + 0.17). Ecoguards rated the importance of cultural heritage opportunities less highly than all the other groups except for the Doukpo members.

Except for cultural heritage services, the data generally shows that ecoguards and local guides place more importance on regulatory and cultural services such as: carbon sequestration, flood control, water purification water, tourism, and education. Village chiefs place less importance on heating and construction materials (along with members of women's associations and IGA and farmers and market gardeners), medicinal resources, and spiritual and religious activities compared to other profiles than other groups.

The results presented in this section highlight the importance and diversity of services provided and supported by mangrove ecosystems. Furthermore, the various statistical analyses conducted allow for an exploration beyond simple mean values, revealing the multiple influences of the values attributed to ecosystem services. In addition to the 12 services mentioned in the survey, some respondents also emphasized other services provided by mangrove ecosystems, such as pollination, support for biodiversity production, and the provision of refuge areas for biodiversity.

Discussion

The ecosystem services provided by mangroves have been assessed and have generally revealed their importance to the local population. Out of the twelve services evaluated, seven scored higher than 3 (moderate importance). The results of this study show that inhabitants living around mangrove ecosystems, especially those in the CBCA Bouche du Roy area, are aware of the services they benefit from and understand the various categories of ecosystem services presented to them during this study. This can be explained by the predominant socio-economic activities of the inhabitants, primarily fishing and salt farming, which depend on mangrove ecosystem services (Cissé *et al.* 2019). In a study conducted in the area, respondents stated that, despite its constraints, protecting the area's ecosystems is beneficial for the inhabitants and their future generations (Kikpa Bio & Dupras 2023). This increasing perception of the importance of ecosystem services confirms, as several studies highlight, the recognition of the multiple and significant services provided by mangrove ecosystems. These services include the provision of fishery products, coastal risk reduction, the creation of strategic habitats for flagship species, as well as their role as significant carbon "sinks" (Diedhiou *et al.* 2021; Ndour *et al.* 2012).

The statistical tests conducted provide information on whether one's profile or occupation is associated with one's perception of the importance of mangrove ecosystem services. The results indicate, firstly, that food provisioning services, water resources, and erosion control services are similarly valued by the different respondent profiles and gender. Except for these three services, regression analysis reveals that respondents with different profiles rate the importance of certain ES differently. In particular, eco-guards and local guides had higher values for regulatory services (carbon sequestration, and flood control, and water purification) and cultural services (tourism and education) than other groups. This could be explained by the complex nature of these types of intangible services, requiring specific knowledge related to a particular profile. Indeed, because of their roles as biodiversity eco-guards or local guides for tourists, these respondents benefit from training and support for mangrove conservation (Kikpa Bio & Dupras 2023; PAGS 2017). Additionally, the eco-guard and local guide profile placed less importance on cultural heritage services than all other respondent profile. Thus, as mangrove ecosystems have multiple functions, the differences in importance rating by profile highlight that individual mangroves ecosystem services provide different values to different groups.

Furthermore, this study demonstrates a weak influence of gender on the perception of the value of different ecosystem services, except for spiritual and religious services where women have placed more importance. This could be explained by spiritual practices and beliefs regarding mangrove ecosystems, which are more prevalent among women. Indeed, in several localities in Benin, religious adherents are mostly women who play important spiritual roles even though some crucial roles are reserved for men (Cordon 2022; Hounkpe 2007). In particular, the community conservation process has led residents to sanctify certain mangrove areas to shield them from anthropogenic pressure (Kikpa Bio *et al.* 2023). Regarding preferences for mangrove ecosystem services, previous studies on gender have found homogeneous preferences for certain types of

services but heterogeneous preferences for others between men and women (Pearson *et al.* 2019; Sy *et al.* 2021; Yang *et al.* 2018). For example, women have shown a better perception of services related to water quality, erosion control, or firewood, while men have valued mitigation services or construction products more (Pearson *et al.* 2019; Yang *et al.* 2018). Finally, the number of women respondents was small, which may have hindered our ability to uncover other differences in their appreciation of various ES relative to that of men.

Similarly, this study provides rich data on the value of each of the three categories of ES and the priority of importance that populations attribute to them. Firstly, provisioning services, especially those related to food, received the highest values. These results are consistent with several studies where provisioning services receive high rates of importance or occurrence (Badiane *et al.* 2019; Diedhiou *et al.* 2021; Ngom *et al.* 2014; Ouedraogo *et al.* 2020; Yildirim *et al.* 2017). Indeed, other studies have shown that provisioning services are most valued as most socio-economic activities of populations depend on them (Badiane *et al.* 2019; Diedhiou *et al.* 2021; Sambou *et al.* 2019). This is particularly noticeable in the use of resources from mangroves, especially fishery products that are consumed and marketed by inhabitants, mainly fishermen (Ashton 2010; Bojang 2009; Brander *et al.* 2012; Giry *et al.* 2017). This predominance of mangrove ecosystems in satisfying local needs justifies the dominant position they occupy and shapes the perception of the populations (Briones Alonso *et al.* 2016; Orekan *et al.* 2018).

Moreover, besides food provisioning services, mangrove ecosystems have shown significant contributions to regulatory services such as carbon sequestration and erosion control. These data are consistent with several studies emphasizing the major role of carbon sequestration and climate regulation as key regulatory functions of mangroves (Alongi 2014; Barbier 2016; Brander *et al.* 2012; Gilman *et al.* 2008; Giry *et al.* 2017; Quevedo *et al.* 2020). For cultural ecosystem services, spiritual, touristic, and cultural heritage services are perceived by populations as having moderate importance. This perception reflects the historical and cultural attachment of populations to these ecosystems and highlights the importance of traditional knowledge associated with mangroves. Similarly, some studies have underscored the significance that communities attach to cultural services as well as ecological knowledge and insights associated with mangroves (Queiroz *et al.* 2017; Sy *et al.* 2021).

The values attributed to the different ecosystem services reveal a diversified perception of mangroves by populations, whether the ES are tangible or intangible. The importance placed on regulatory services in our study differs from some studies conducted in other types of ecosystems, where intangible services are often less appreciated (Barnaud *et al.* 2011; Yildirim 2017). This discrepancy can be explained by the protection and awareness efforts deployed in favor of mangroves, which have faced significant anthropogenic and climatic pressure (Bojang 2009; Sambou *et al.* 2019; Sinsin *et al.* 2018). Particularly in our study area, various protection and natural resource management initiatives, as well as the official establishment of the Bouche du Roy CBCA in 2016, have fostered exchanges among stakeholders regarding the importance of the benefits of mangroves (Kikpa Bio et al. 2025; PAGS 2017).

The results show lower importance ratings for water resources, medicinal, water purification, and education services, revealing a limited understanding of the benefits of these services or limited use by inhabitants (Giry *et al.* 2017). These low importance ratings can also be attributed to the lack of information or knowledge among populations regarding certain complex services, such as water purification by ecosystems (Daily 1997; Sy 2019). However, in addition to the twelve ES analyzed, some respondents often identified, during the post-survey, pollination services in the category of regulatory ES and biodiversity production support services in the category of supporting ES. These services provided by the mangrove ecosystems of the CBCA are also considered important by the respondents. The survey and post-survey debriefing reveal that respondents are aware of both direct and indirect use ES as well as non-use ES of mangrove ecosystems.

Food provision followed by carbon sequestration and erosion control received the highest importance ratings, with food provision and erosion control being equally valued by the various profiles, while carbon sequestration being highly valued by all groups, but more so by respondents involved in agriculture or environmental activities, key interest groups in relation to climate change. The analysis of mangrove ES perception can thus provide a conceptual and operational framework to garner local community interest and highlight the multiple functions of biosphere reserve ecosystems, where certain uses are permitted (Aubin *et al.* 2014; Barnaud *et al.* 2011; Ngom *et al.* 2014). In particular, the prioritization of services based on their importance to the community helps to underscore social demand and awareness needs (Diedhiou *et al.* 2021; Queiroz *et al.* 2017; Yildirim 2017). Moreover, in a context of controversy and uncertainty related to ES, a study that seeks the opinions of local stakeholders involved in biodiversity protection to engage in the ES debate and contribute to the implementation of more appropriate and socially accepted measures (Arnauld de Sartre *et al.* 2014; Barnaud *et al.* 2011;

Sambou *et al.* 2019). Indeed, while the population benefits from ES, it can also contribute to their production, justifying the importance of employing socio-ecological approaches in ecosystem and biodiversity protection (Barnaud *et al.* 2011). Thus, strengthening traditional practices and knowledge, as well as involving various stakeholders of the CBCA in ES support, are essential elements of a natural resource management strategy.

Conclusion

Our evaluation of the Bouche du Roy Community Biodiversity Conservation Area (CBCA) local population's perception of the ecosystem services (ES) provided by mangrove ecosystems has revealed that residents have a good understanding of the various categories of ES and are aware of the benefits they derive from them. Our results suggest that the successful protection of mangrove ecosystems, which depends on social acceptance, relies on several factors, including their ability to provide livelihoods, climate and coastal regulation, as well as cultural, spiritual, and touristic values.

This research underscores the significant socio-economic role that mangrove ecosystems play for populations, thus justifying the need to continue implementing ecosystem protection strategies in a more holistic manner, integrating the interests of the local communities with and for whom protection measures are put in place. It provides scientists, stakeholders, and authorities with critical information on communities' perception of mangrove services, thereby contributing to the development of approaches that support the interests of the local community in mangrove ecosystem management plans.

Declarations

List of abbreviations: CBCA - Community Biodiversity Conservation Area; CI- confidence intervals; ES - ecosystem services; Ha - hypothesis alternative; Ho – hypothesis; IGA - income-generating activities; MEA - Millennium Ecosystem Assessment; MLR - multiple linear regression; NGO - non-governmental organizations; SD - standard deviation; SE - standard error

Ethics approval and consent to participate: Researchers obtained ethical approval from the Université du Québec en Outaouais (UQO) based on the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans, before the research began.

Consent for publication: Not applicable

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