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Valuation and Mapping of Marine Ecosystem Services in the Jordanian Gulf of Aqaba, Red Sea

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Abstract

Marine ecosystems play a vital role in supporting human well-being and coastal communities, offering essential ecosystem services (ES). This study focuses on the Gulf of Aqaba in Jordan, aiming to assess and map marine ecosystem services by leveraging stakeholder perceptions. To achieve this objective, a comprehensive survey was conducted with 64 participants representing diverse demographics. The survey, coupled with Participatory Geographic Information System (PGIS) exercises, gathered data on the awareness and valuation of ecosystem services. The integration of PGIS, a participatory mapping methodology, facilitated stakeholder involvement in spatial mapping exercises. This approach not only captured local knowledge but also enhanced the mapping process, providing a more nuanced and comprehensive understanding of stakeholder perspectives on marine ecosystem services in the Gulf of Aqaba. The results contribute to evidence-based decision-making, sustainable resource management, and the implementation of international agreements and policies for marine conservation and development in this ecologically important region.

Keywords: Marine Ecosystem Services, Mapping, PGIS, Aqaba

1. Introduction

Marine ecosystems are integral to global well-being, offering essential ecosystem services (ES) vital for human welfare and coastal communities (Ma et al., 2023; Costanza et al., 2014; Barbier et al., 2011). Recognized for provisioning, regulating, cultural, and supporting services, these ecosystems play a multifaceted role in sustaining life (Asante et al., 2023; Burkhard et al., 2012, 2014; Van de Pol et al., 2023). The ecosystem-based approach (EBA) has emerged as a key framework for incorporating ES into decision-making, providing a holistic perspective crucial for long-term societal sustainability (Ruskule et al., 2023; Costanza et al., 2014).

This study focuses on the Gulf of Aqaba in Jordan, employing EBA to map and understand marine ES for effective decision-making, resource management, and alignment with international conservation and development policies (Cordero-Penín et al., 2023; Béné et al., 2016). Drawing inspiration from relevant studies, particularly those employing Participatory Geographic Information Systems (PGIS) methodologies, this research adopts a stakeholder perception approach (Brown et al., 2014). Notably, Brown et al. (2014) demonstrate the efficacy of PGIS in assessing social and cultural values associated with public lands, revealing significant associations between values, land types, and potential management conflicts. In their studies conducted in 2015 and 2016, Brown and colleagues, as well as the work by Munro and colleagues in 2017, redirect attention towards marine ecosystems. They emphasize the significance of stakeholder engagement and participatory approaches, delving into a nuanced examination of stakeholder perspectives and their impact on mapping outcomes.

Expanding beyond specific regions, Burdon et al. (2019) emphasize a stakeholder-driven approach to understanding marine natural capital and societal benefits, showcasing its global significance. Hermes et al. (2018) provide an editorial overview, stressing the diverse methods for assessing recreational ecosystem services (RES) and the necessity of integrating RES information into decision-making. Karimi et al. (2015) contribute insights into social-ecological hotspots, demonstrating the need for integrating social and ecological data. Wangai et al. (2016) extend the scope to Africa, advocating for localized assessments and addressing trade-offs and synergies. This collective body of literature establishes a foundation for understanding and mapping marine ecosystem services, with a focus on stakeholder engagement, participatory GIS methodologies, and the integration of diverse perspectives as crucial elements for comprehensive marine management.

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2. Materials and Methods

2.1. Study Area

Aqaba, a coastal city located in the southern part of Jordan along the northeastern coast of the Red Sea, was chosen as the study site. Positioned strategically at the northern tip of the Gulf of Aqaba, which is an extension of the Red Sea, Aqaba offers a remarkable environment for the investigation. The region is renowned for its rich marine biodiversity and unique coral reef ecosystems, making it a significant hotspot for marine ecosystem services. With geographical coordinates ranging from approximately 29°27'N to 29°36'N latitude and 34°57'E to 35°03'E longitude, Aqaba boasts a coastline stretching over 27 kilometres, encompassing diverse marine habitats such as coral reefs, seagrass meadows, and rocky shores, each providing distinct ecosystem services (Al-Najjar et al. 2019). The Gulf of Aqaba, a semi-enclosed water body, represents the northernmost extension of the Red Sea and is connected to its main body via the Strait of Tiran (Al-Najjar et al. 2019). Stretching approximately 180 km in length, with a width of 14-24 km, and reaching a maximum depth of 1825 m, the study area is bordered by arid deserts (Khalaf et al. 2019). The Jordanian coastline extends for 27 km, and the width of the Gulf bordered by Jordan ranges from 5 km at the northern border to 17 km at the southern border (Al-Najjar et al. 2018) (Figure 1). Along most of the coastline throughout the Gulf, fringing reefs can be found, adding to the region's ecological significance.

Figure 1. Study area - Aqaba coastline – Jordan.

Table 1, which presents the demographic information of the participants, shows a diverse range of ages, occupations, and educational backgrounds. This diversity is crucial for understanding the varied perspectives on ecosystem services. The table highlights a significant representation of young adults, which aligns with the emerging environmental consciousness observed in the survey responses.

Figure 2, depicting the GIS map of ecosystem service distribution, illustrates significant spatial variations. The coastal regions near urban centers show a higher dependence on ecosystem services, as indicated by the denser color gradients. This pattern underscores the intricate relationship between urban development and marine ecosystems.

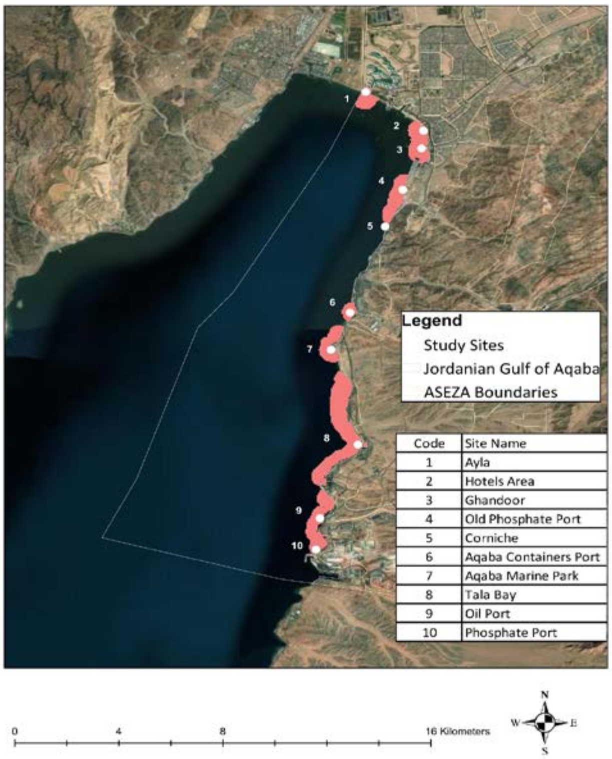

Figure 2. Corals-seagrass interaction areas as a result of the snorkeling and GIS analysis.

2.2. Data Collection

The flow of data collection is depicted in Figure 3 Snorkeling surveys were conducted along the 27 km shoreline of the Gulf of Aqaba, resulting in a total of 8,278 data points collected from 45 sites. For each point, the prevalent habitat (corals, seagrass, rocks, and sand) was recorded. After that, a GIS map reflecting the 10 most dominant corals–seagrass interaction sites along the entire coastline was prepared. To assess marine ecosystem services along the 10 sites, we used a stakeholder perception approach, incorporating the perspectives of coastal users through a questionnaire survey (Appendix 1).

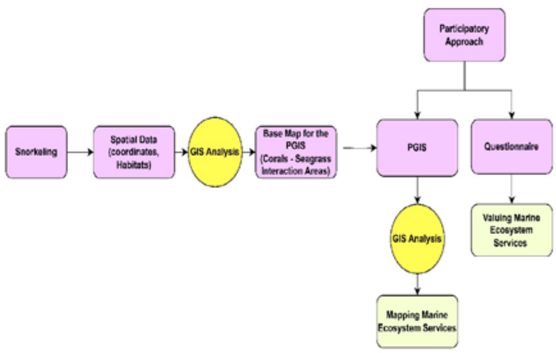

Figure 3. Adopted methodology for data collection and analysis.

The questionnaire captured information on stakeholders' awareness, utilization, preferences, and perceived importance of marine ecosystem services. It included sets of questions to gather demographic information, assess awareness of ecosystem services, evaluate the importance of services, and identify their locations on a map. Respondents were given the flexibility to specify additional services and provide qualitative insights on sustainable management and conservation actions in Aqaba.

To incorporate spatial local knowledge about the locations of marine ecosystem services, we employed the Participatory Geographic Information Systems (PGIS) approach within the identified corals-seagrass interaction areas in the questionnaire. Utilizing GIS, the acquired spatial data were used to develop maps representing the distribution of ecosystem services based on marine resource users' perceptions.

2.3. Data analysis

The collected data from the questionnaire survey underwent statistical analysis to determine the relative importance of each identified marine ecosystem service. Descriptive statistics, including means and percentages, were calculated to summarize the rankings provided by the respondents, offering an initial indication of the perceived importance of different services and enabling comparisons among them. A higher ranking assigned to a service indicated a greater perceived value or importance.

To map the corals-seagrass interaction areas and marine ecosystem services, GIS technology was employed to enable spatial representation and visualization across the study area. The process involved several key steps:

1. Data Preparation: The initial step involved integrating the percentages of responses from the participants who identified marine ecosystem services along the 10 sites into the attribute table of the GIS data layer representing these locations. This data integration ensured that it was ready for further spatial analysis.
2. Spatial Interpolation: Spatial analysis was conducted using the Inverse Distance Weighting (IDW) interpolation method. This process aimed to estimate values for the remaining points that lacked responses, creating a continuous surface representing the

distribution of marine ecosystem services across the entire study area. The interpolation provided valuable insights into the spatial distribution of identified ecosystem services, enabling a comprehensive visualization of the phenomena.

3. Define Study Area: To focus the representation within the borders of the Gulf of Aqaba, the raster data resulting from the spatial interpolation was clipped. This step ensured that the visualization was limited to the specific area of interest, making the map's context clear and relevant to the study's objectives.

Visualization: The final step involved visually representing the results using a gradient colour scheme. Distinct colours were assigned to different values or ranges of percentages of marine ecosystem services identified. For instance, areas with lower percentages of marine ecosystem services were depicted using green, while areas with higher percentages were represented using red. The gradient between green and red effectively showcased the varying levels of presence and absence of marine ecosystem services across the study area, providing an easily interpretable map for the stakeholders and decision-makers.

2.4. Demographics of Study Participants

Figure 4 details the demographics of our 64 study participants. The gender breakdown shows 61% male and 39% female participants. Age distribution was varied, with 16% under 18 years, 19% between 18 and 24, 25% between 25 and 34, 16% between 35 and 44, and 24% over 45 years old. Occupationally, participants included 9% coastal community members, 45% tourists or visitors, and 41% local business owners or employees. No participants were from environmental, governmental, or policy sectors, with 5% categorizing their occupation as "Other." Educationally, 28% completed primary or secondary education, 36% held bachelor's degrees, 27% had master's degrees, and 9% possessed Ph.Ds or equivalent, with no "Other" educational backgrounds reported.

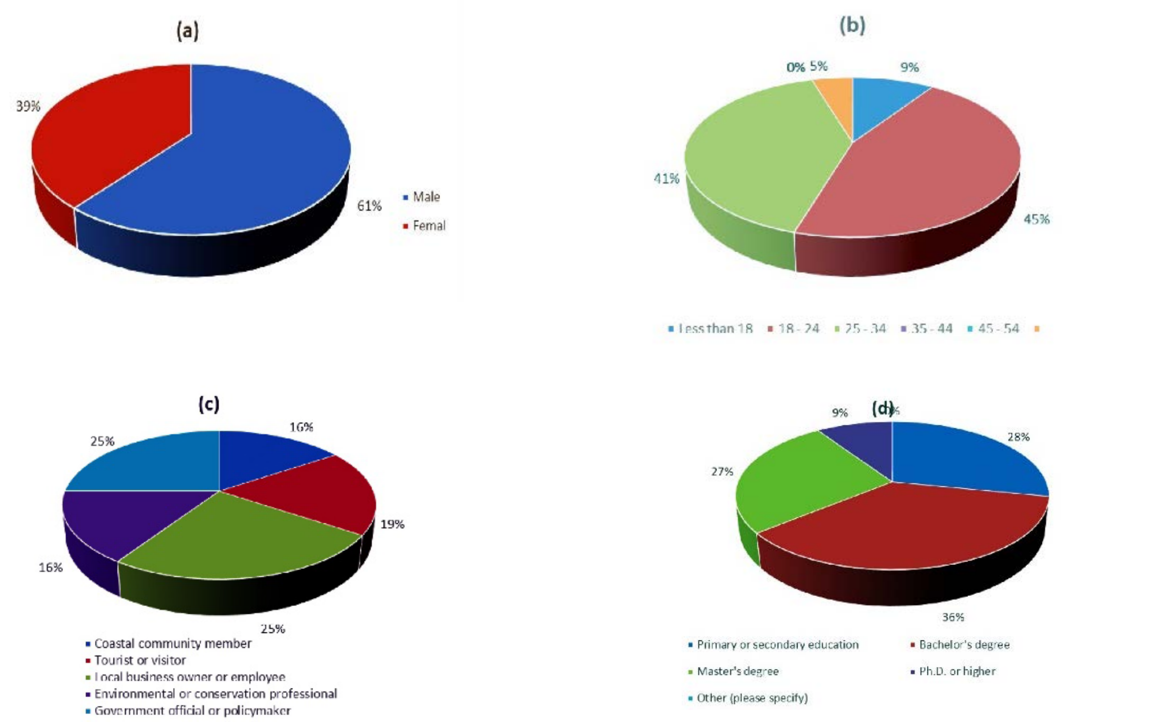

Figure 4. Demographic information about the study participants: (a) Gender, (b) Age, (C) Occupation, (d) Education Level.

2.5. Awareness of Ecosystem Services

Survey findings (Figure 5a) show varied understanding of marine ecosystem services among participants. Sixteen percent were very familiar, 41% moderately familiar, 28% slightly familiar, and 16% unfamiliar. This underscores the need for enhanced public education on marine ecosystems' ecological importance in Aqaba.

Regarding threats to these services (Figure 5b), 22% were very aware, 44% moderately aware, and 34% slightly aware, with no participants completely unaware. This highlights the success of existing public awareness campaigns and the importance of their continuation for marine ecosystem conservation in Aqaba.

(a) (b)

Figure 5. Results of the questionnaire: (a) familiarity with the concept of marine ecosystem services, (b) awareness of potential threats facing marine ecosystem services in Aqaba.

2.6. Prioritization of Marine Ecosystem Services

Participants' ranking of marine ecosystem services (Figure 6) reveals diverse valuations. Provisioning services were ranked first by 22% and second by 28%, showing appreciation for tangible benefits. Regulating services were top priority for 47% and second for 28%, indicating an understanding of ecological balance importance. Cultural services ranked third by 39%, reflecting a balance of priorities. Supporting services were first for 13% but third for 39%, showing varied significance.

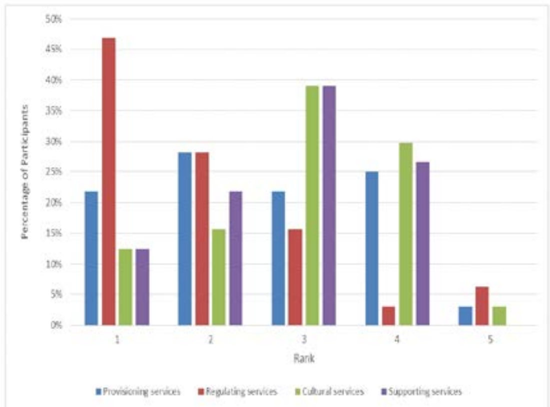

Figure 6. Identifying and valuing marine ecosystem services.

In Figure 7, all participants acknowledged awareness of threats to these services. Provisioning services ranked as top priority for 3%, second for 30%, but third for 48%. Regulating services were top for 3%, third for 31%, but fifth for 25%. Cultural services were most important for 6%, but fifth for 31%. Supporting services ranked first by 20%, second by 19%, but fifth by 14%.

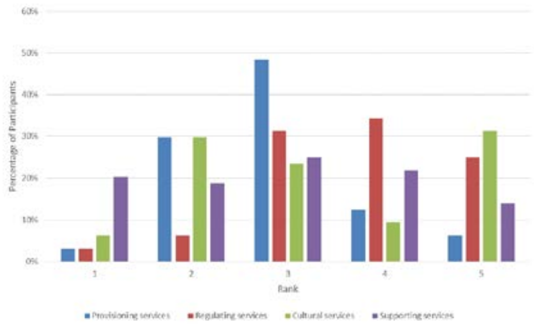

Figure 7. Awareness of potential threats to marine ecosystem services in Aqaba.

2.7. Locations of Marine Ecosystem Services

PGIS findings (Figure 8) indicate participant perceptions of marine ecosystem services across ten Aqaba coastline sites. Aqaba Marine Park was highlighted by 39% for significant ecological benefits. Tala Bay followed with 31%. Lower perceived ecosystem services were noted in Ghandoor, Old Phosphate Port, and Phosphate Port (9% each). The Hotels Area and Aqaba Containers Port were recognized by 22% and 9%, respectively. The Corniche and Oil Port each received 9% acknowledgments for their ecological contributions.

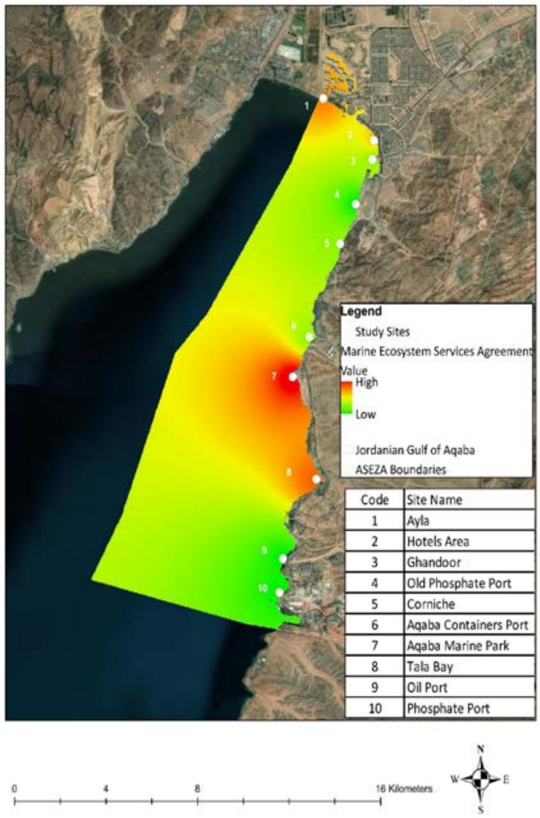

Figure 8. Level of agreement on the locations of marine ecosystem services as a result of the PGIS.

3. Discussion

The collection of demographic data from participants in our study was crucial for understanding the varied perspectives that influence the identification of ecosystem services in the Gulf of Aqaba, Jordan. We engaged a demographically diverse group, including individuals from different generations, with equal representation of genders and a wide age range. This diversity enriched our assessment of ecosystem service preferences and highlighted the importance of including varying viewpoints in such studies (Milfont & Sibley, 2012). We focused on stakeholders like coastal community members, tourists, and local business affiliates, emphasizing their critical role in ecosystem services management (Christie et al., 2017). However, the exclusion of environmental experts and government officials from our study participants indicates an area for improvement in future research, emphasizing the need to incorporate their specialized knowledge into ecosystem services mapping (Daw et al., 2011).

Our findings also showed that educational backgrounds significantly influence perceptions of ecosystem services. We observed a wide range of educational levels among participants, from those with primary or secondary education to a smaller cohort with doctoral or higher qualifications (Chan et al., 2016; Liquete et al., 2013). The presence of a substantial number of participants with bachelor's and master's degrees suggests a heightened level of environmental awareness, beneficial for informed decision-making in ecosystem services management. This robust demographic data collection aids in understanding how sociodemographic factors impact ecosystem service preferences, reinforcing the importance of involving a diverse range of stakeholders in the development of sustainable ecosystem management policies (Plieninger et al., 2013).

Awareness of marine ecosystem services is vital for stakeholder engagement and fostering environmental consciousness in the region (Tamire et al., 2023; Gifford, 2011). Our study revealed varied levels of familiarity with marine ecosystem services among participants, with a considerable number only moderately knowledgeable. This finding points to the need for targeted initiatives to enhance understanding of the role of marine ecosystems in providing essential services in Aqaba.

Our survey also indicated a promising level of awareness among participants about potential threats to marine ecosystem services in Aqaba. Most participants exhibited at least a moderate awareness, with many highly informed about these threats. This awareness is a valuable asset for conservation efforts and informed decision-making aimed at protecting the region's marine biodiversity and ecosystem services. However, maintaining this awareness requires continuous educational and communication initiatives to keep stakeholders engaged and proactive in addressing challenges to marine ecosystem services in Aqaba.

The valuation of marine ecosystem services was revealed as a complex process, reflecting varied priorities among participants (Saarikoski et al., 2022; Chan et al., 2016). Provisioning services, like fishery resources, were highly valued for their direct benefits. However, the limited focus on other provisioning benefits like raw materials or medicinal resources suggests a gap in understanding their broader ecological contributions.

Participants also expressed diverse views on regulating services, crucial for maintaining environmental balance. This diversity in perspectives necessitates tailored communication strategies to convey the importance of regulating services and their interconnectivity with other ecosystem functions.

Cultural services, offering non-material benefits, were valued differently by participants, underlining the need to accommodate diverse cultural perspectives in ecosystem management strategies.

The study also highlighted the importance of supporting services, foundational for other ecosystem services. These services were viewed as significant by participants, even if not always ranked as the top priority.

Our study highlights the critical need for an inclusive approach to ecosystem management in the Gulf of Aqaba. Recognizing and valuing the diverse perspectives and priorities of various stakeholders is key to fostering sustainable practices and preserving the marine ecosystems in the region (Díaz-Siefer et al., 2023).

The study's results show a positive trend in participants' awareness of potential threats to marine ecosystem services in Aqaba, indicating that environmental education efforts have had a certain impact. However, to maintain and enhance this level of awareness, ongoing educational initiatives are vital to ensure the community remains actively informed and engaged in conservation efforts.

Furthermore, the analysis of ecosystem services rankings reflects the different levels of importance assigned by participants, underscoring the necessity for tailored communication strategies and inclusive approaches in ecosystem management. The application of Participatory Geographic Information Systems (PGIS) in our research provided critical insights into local community perceptions of marine ecosystem services along the Aqaba coastline. This approach highlighted the ecological significance of specific areas and pinpointed locations where increased awareness and education could be beneficial (Carriea et al., 2022).

Collectively, the integration of demographic data, awareness levels, and PGIS findings offers a comprehensive framework for decision-makers, policymakers, and environmental managers. This integrated approach supports the development of informed, inclusive, and participatory strategies for effective marine ecosystem management in the Gulf of Aqaba.

4. Conclusions

This study emphasizes the critical role of incorporating stakeholder perceptions and values in the identification and mapping of marine ecosystem services in Aqaba, Jordan. It underscores the vital importance of stakeholder engagement and the integration of diverse perspectives in marine ecosystem management. Key highlights of this study include:

- The essential role of stakeholder engagement in providing valuable insights for effective conservation and management strategies, ensuring a comprehensive understanding of marine ecosystem services.
- The importance of inclusive decision-making processes that integrate diverse perspectives, leading to more informed and holistic approaches to marine ecosystem management. This integration prioritizes the well-being of both human communities and nature.
- The necessity of ongoing educational campaigns to maintain and enhance stakeholders' awareness of potential threats to marine ecosystem services.

- The use of Participatory Geographic Information Systems (PGIS) as a community-centered approach, which incorporates local knowledge and makes conservation efforts more meaningful and relevant.
- The empowerment of decision-makers through the GIS map to effectively prioritize conservation actions and sustainable development efforts.
- The contribution of understanding marine ecosystem services to the development of evidence-based policies and practices that promote human well-being and ecological preservation.
- The development of holistic conservation strategies by incorporating stakeholder perspectives, leading to more inclusive and effective strategies for safeguarding the marine environment's health and resilience.
- The emphasis on continuous efforts to engage stakeholders and integrate diverse perspectives for the long-term sustainability of marine ecosystem services in the Gulf of Aqaba.

In essence, the findings of this study offer a valuable resource for coastal management and marine conservation efforts. By acknowledging and integrating the values and perceptions of local communities, the study fosters a balanced relationship between human activities and the marine environment. This approach supports the well-being of both coastal communities and nature in the Gulf of Aqaba, highlighting the synergy between human development and environmental stewardship.

5. Recommendations

Based on our findings, we urge the adoption of an inclusive approach to marine ecosystem management in Aqaba, emphasizing the need for robust stakeholder engagement and participatory decision-making processes. Key actions include launching targeted educational campaigns to raise public awareness about marine ecosystems' value and threats, and expanding the use of Participatory Geographic Information Systems (PGIS) to incorporate local knowledge in conservation strategies. We recommend fostering collaborations among government agencies, environmental groups, and the community to develop policies that balance ecological preservation with human needs. Additionally, continuous research and adaptive management practices are essential to address emerging challenges and ensure the sustainability of marine biodiversity and ecosystem services in the region.

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Appendix 1

Perception of Marine Ecosystem Services in Aqaba: Stakeholder Questionnaire

Introduction:

Thank you for participating in this survey on marine ecosystem services in Aqaba. The purpose of this questionnaire is to gather your perceptions and insights regarding the various ecosystem services provided by the marine environment in Aqaba. Your valuable input will contribute to a better understanding and appreciation of these services, ultimately aiding in their sustainable management and conservation. Please answer the following questions to the best of your knowledge and experiences.

Section One: Demographic Questions:

1. **Gender**
   a) Male b) Female ~~c)~~

2. **Age**
   a) Under 18 b) 18-24 c) 25-34
   d) 35-44 e) 45-54 f) 55 and above

3. **Occupation**
   a) Coastal community member b) Tourist or visitor c) Local business owner or employee
   d) Environmental or conservation professional e) Government official or policymaker f) Other (please specify)

4. **Educational Background:**
   a) Primary or secondary education b) Bachelor's degree c) Master's degree
   d) Ph.D. or higher e) Other (please specify)

Section Two: Awareness about Ecosystem Services

5. **How familiar are you with the concept of marine ecosystem services?**
   a) Very familiar
   b) Moderately familiar
   c) Slightly familiar
   d) Not familiar

How aware are you of the potential threats facing marine ecosystem services in Aqaba?
   a) Very aware
   b) Moderately aware
   c) Slightly aware
   d) Not aware

Section Three: Identifying and Valuing Ecosystem Services

Please rank the following marine ecosystem services in terms of their importance to you personally (1 being the most important and 5 being the least important):
   a) Provisioning services (e.g., seafood, medicinal plants)
   b) Regulating services (e.g., climate regulation, water purification)
   c) Cultural services (e.g., recreation, spiritual significance)
   d) Supporting services (e.g., nutrient cycling, habitat formation)
   e) Other (please specify)

How would you evaluate the importance of the identified marine ecosystem services in Aqaba? (Rate each service on a scale of 1-5, with 1 being very low importance and 5 being very high importance)
   a) Provisioning services (e.g., seafood, medicinal plants)
   b) Regulating services (e.g., climate regulation, water purification)
   c) Cultural services (e.g., recreation, spiritual significance)
   d) Supporting services (e.g., nutrient cycling, habitat formation)

e) Other (please specify)

Section ٤: Identifying Locations of Ecosystem Services

6. **Which specific coastal areas in Aqaba (From the attached Map) have you observed or experienced the following marine ecosystem services?** <u>(Select all that apply)</u>
7. **Please indicate the relative abundance or occurrence of the following ecosystem services in each of the selected coastal areas** <u>(Use a scale of 1-5, with 1 being very low and 5 being very high)</u>

Coastal Area (1): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (2): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (3): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (4): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (5): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (6): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (7): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (8): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (9): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Coastal Area (10): [Insert Selected Coastal Area]

a) Provisioning services (e.g., seafood, medicinal plants)
b) Regulating services (e.g., climate regulation, water purification)
c) Cultural services (e.g., recreation, spiritual significance)
d) Supporting services (e.g., nutrient cycling, habitat formation)
e) Other (please specify)

Section 4: Conclusion

8. In your opinion, what are the key actions that should be taken to ensure the sustainable management and conservation of marine ecosystem services in Aqaba? (Open-ended question)

Thank you for your participation in this survey! Your input is greatly appreciated and will contribute to our understanding of marine ecosystem services in Aqaba.