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RECEIVED 19 November 2025  
REVISED 31 December 2025  
ACCEPTED 27 January 2026  
PUBLISHED 18 February 2026

## CITATION

Alhawaish AK (2026) The hidden currents of marine economies: assessing informal market behavior across fisheries, tourism, and logistics in Saudi Arabia's Eastern Province. *Front. Mar. Sci.* 13:1750173. doi: 10.3389/fmars.2026.1750173

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# The hidden currents of marine economies: assessing informal market behavior across fisheries, tourism, and logistics in Saudi Arabia's Eastern Province

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**Introduction:** The Blue Bioeconomy is widely recognized as a driver of sustainable coastal development; however, its hidden dimensions, particularly informal market behavior, unreported transactions, and financial leakage, remain significantly understudied in rapidly evolving marine economies. Existing research has largely emphasized environmental sustainability and sectoral growth, with limited empirical attention to financial opacity and informal economic practices across Blue Bioeconomy sectors in the Gulf and Saudi Arabian context. This study addresses this gap by examining stakeholder perceptions of hidden economic dynamics within Saudi Arabia's Eastern Province.

**Methods:** A mixed-methods research design was employed, drawing on data collected from 404 stakeholders representing government agencies, private industry, academia, non-governmental organizations, and coastal communities. The analysis focused on fisheries, marine tourism, and maritime logistics, with aquaculture examined as a complementary sector. Quantitative methods included descriptive statistics, reliability testing, exploratory factor analysis, and multiple linear regression to identify predictors of perceived financial leakage. Qualitative data from open-ended survey responses were analyzed using thematic coding.

**Results:** The findings indicate widespread concern regarding weak regulatory enforcement, fragmented institutional mandates, limited data transparency, and persistent informal transactions within high-value coastal sectors, particularly fisheries and tourism. Exploratory factor analysis identified three latent dimensions, Institutional Weakness, Sectoral Economic Pressure, and Transparency Culture, that shape vulnerability to financial leakage. Regression results show that institutional weakness and economic pressure are the strongest predictors of perceived underreporting. Qualitative insights further reveal gaps in monitoring systems, inconsistent auditing practices, and community-level behaviors that circumvent formal reporting mechanisms.

**Discussion:** The results highlight the importance of addressing hidden economic dynamics to advance a transparent, innovation-driven Blue Bioeconomy aligned with Saudi Arabia's Vision 2030. Strengthening regulatory enforcement, improving financial transparency, and enhancing institutional coordination are critical to reducing financial leakage. Policy implications include the adoption of digital reporting systems, reinforced auditing mechanisms, improved inter-

agency coordination, and the integration of community-based monitoring frameworks. This study contributes novel empirical and theoretical insights into the intersection of marine governance, financial transparency, and informal economic behavior in emerging coastal economies.

#### KEYWORDS

blue bioeconomy, Eastern Province, financial leakage, fisheries, informal market behavior, marine governance, marine tourism, maritime logistics

## 1 Introduction

The Blue Bioeconomy has become a central pillar of contemporary sustainability and development frameworks, emphasizing the efficient, responsible, and innovative use of marine and coastal resources to support economic diversification, ecological resilience, and community well-being (World Bank, 2017; OECD, 2020; FAO, 2022). Globally, governments and international organizations increasingly promote Blue Economy strategies as pathways to address food security, employment generation, climate adaptation, and technological innovation in coastal regions. Fisheries, aquaculture, marine tourism, and maritime logistics are widely recognized as key engines of growth within this paradigm, particularly in regions seeking to transition toward low-carbon and knowledge-based economies. However, while the formal benefits of Blue Bioeconomy development are well documented, significantly less attention has been given to the informal, opaque, and weakly regulated economic practices that operate beneath official policy narratives and statistical reporting systems.

Across many marine economies, these “hidden currents” take the form of informal market behavior, unreported transactions, institutional leakage, and financial opacity that distort sectoral performance and undermine governance effectiveness (APEC, 2008; FAO, 2009; Bilawal Khaskheli et al., 2023). Global evidence indicates that such practices are not marginal anomalies but systemic features of marine value chains when regulatory capacity, enforcement consistency, and transparency mechanisms are insufficient (FAO, 2001; Cheung, 2013; Davidson et al., 2019; Wang et al., 2024). In fisheries, discrepancies between reported and actual catch volumes have been widely documented, often exceeding 20–30% in some regions, with implications for stock assessments, conservation planning, and revenue collection (Gallic and Cox, 2006; Cheung, 2016). Similarly, in coastal tourism and maritime logistics, cash-based transactions, unlicensed operations, and fragmented oversight can result in significant financial leakage and weak accountability. These shadow practices undermine fair competition, disadvantage compliant operators, and weaken the credibility of sustainability-oriented marine policies.

Within the Arabian Gulf, and particularly in Saudi Arabia’s Eastern Province, the relevance of these hidden dynamics is intensifying. The Eastern Province represents one of the Kingdom’s most strategically significant coastal regions, hosting major fisheries, expanding aquaculture ventures, rapidly growing marine and coastal tourism, and globally connected ports and logistics hubs. Together, these sectors underpin national food

security, employment, and regional trade flows, and they form a critical component of Saudi Arabia’s Vision 2030 agenda for economic diversification and sustainable development (Saudi Vision, 2016; GCC, 2024). At the same time, the pace of sectoral expansion has often outstripped the evolution of integrated governance, monitoring, and reporting systems. Regional studies and Gulf-based marine experts have repeatedly highlighted concerns regarding fragmented institutional mandates, uneven enforcement capacity, and limited data transparency, all of which create structural conditions that enable informal market behavior and underreporting (Al-Yamani et al., 2007; Burt, 2014; Alhawaish, 2025).

Understanding these hidden financial and institutional dynamics is critical because their consequences extend far beyond immediate revenue losses. Unreported transactions distort market competition, undermine compliance incentives, weaken fish stock assessments, and reduce the effectiveness of conservation and spatial planning efforts (Drammeh, 2000; Gallic and Cox, 2006; Bilawal Khaskheli et al., 2025). They also erode trust between regulators, industry actors, and coastal communities, thereby weakening governance legitimacy. In emerging economies, where regulatory frameworks and monitoring technologies are still evolving, such distortions complicate evidence-based policymaking and reduce the effectiveness of strategic national initiatives. For Saudi Arabia, which places strong emphasis on transparency, digital transformation, and high-value diversification under Vision 2030, informal marine economic practices represent both a governance risk and a missed opportunity for sustainable growth.

Despite the growing recognition of these challenges, empirical research on informal market behavior and financial opacity in Saudi Arabia’s marine sectors remains limited. Existing studies in the Kingdom and the wider GCC have predominantly focused on environmental pressures, sectoral development opportunities, or institutional constraints within the Blue Economy (Sheppard and Loughland, 2002; Humood, 2013; Alhawaish, 2016; Robitzsch et al., 2023). Much less attention has been paid to the underlying economic behaviors that shape how value is generated, reported, and distributed within marine value chains. In particular, no prior study has systematically examined how unreported transactions, sectoral economic pressure, and institutional weaknesses interact across multiple Blue Bioeconomy sectors in Saudi Arabia’s Eastern Province using a large, stakeholder-based dataset.

This study addresses these gaps by examining the hidden currents of marine economic activity through a mixed-methods assessment of stakeholder perceptions. Drawing on survey data

from 404 respondents representing government agencies, private firms, non-governmental organizations, academia, and coastal communities, the research seeks to identify which Blue Bioeconomy sectors are perceived as most vulnerable to informal market behavior; to analyze the institutional, economic, and cultural drivers of underreporting; and to assess how stakeholder characteristics and governance perceptions shape concerns about financial leakage. By integrating quantitative and qualitative evidence, the study provides a holistic understanding of the informal forces shaping marine economic systems and offers policy-relevant insights to support Saudi Arabia's transition toward transparent, sustainable, and innovation-driven Blue Bioeconomy governance.

The remainder of this manuscript is structured as follows. Section 2 reviews the global and regional literature on Blue Bioeconomy governance, shadow economic practices, and financial leakage. Section 3 outlines the methodological framework. Section 4 presents the empirical results. Section 5 discusses the findings in relation to existing literature and policy debates, while Section 6 and 7 concludes by highlighting key implications and directions for future research.

## 2 Literature review

### 2.1 Global perspectives on the blue bioeconomy

The Blue Bioeconomy has become a cornerstone of global sustainability agendas, emphasizing the transformation of marine resources into economic, social, and ecological value (OECD, 2020; FAO, 2022). Encompassing sectors such as fisheries, aquaculture, coastal tourism, biotechnology, and maritime transport, it relies on the effective and sustainable utilization of aquatic ecosystems (World Bank, 2017). By 2030, the global Blue Economy is projected to surpass USD 3 trillion, driven by innovations in marine-based industries, growing demand for seafood, and coastal urbanization (OECD, 2016). This rapid expansion has prompted governments and development institutions to adopt strategies that integrate economic diversification with marine ecosystem protection.

Yet beneath this growth lies a set of hidden currents, structural inefficiencies, informal market behavior, and financial leakages that threaten long-term sustainability. International studies highlight widespread underreporting, cash-based exchanges, and unregulated transactions across fisheries, aquaculture, and marine tourism (FAO, 2001; FAO, 2006; Holland, 2018; OECD, 2024; Wang et al., 2024; Aminian-Biquet et al., 2024). The FAO (2009), for example, estimates that up to 20–30% of global fisheries production is underreported, largely due to weak monitoring, unregulated landings, and informal trading networks. Such practices distort official statistics, weaken resource management, undermine fiscal

revenue, and encourage opportunistic behavior in rapidly growing coastal economies.

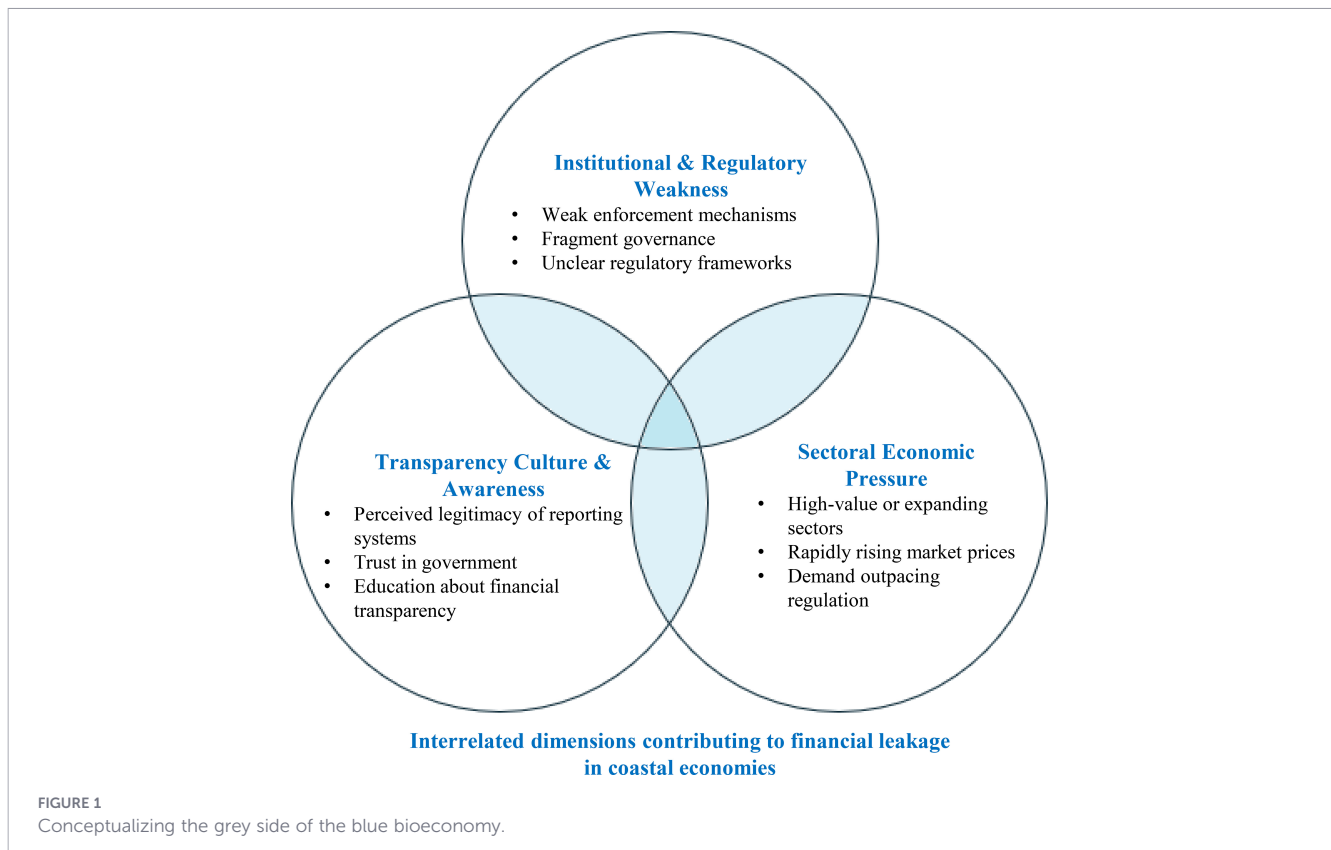
Similar patterns appear in coastal tourism and maritime logistics. Research from Southeast Asia, West Africa, and Mediterranean regions indicates that unreported tourism revenues, informal transport services, undocumented port fees, and fragmented auditing contribute substantially to financial opacity in coastal value chains (Alder and Sumaila, 2004; Goñi et al., 2008; Park et al., 2020; Bilawal Khaskheli et al., 2023). These shadow transactions are especially prevalent where regulatory oversight is weak or split between multiple agencies. Thus, the global literature emphasizes that financial leakage is not a marginal phenomenon but rather an embedded feature of marine economic systems, particularly in sectors characterized by high market value, fast growth, and low monitoring capacity.

### 2.2 The GCC context: governance, informality, and regional vulnerabilities

Across the Gulf Cooperation Council (GCC), Blue Economy development has gained momentum as countries diversify beyond hydrocarbons and leverage marine assets to support economic transformation (GCC, 2024). The region's historical dependence on fisheries, pearling, shipping, and maritime trade has expanded to include coastal tourism, aquaculture, and offshore energy (Burt, 2014; Saleh and Munir, 2023). However, governance of marine sectors remains fragmented, with responsibilities divided among ministries of environment, fisheries, investment, municipal affairs, and transport. This overlapping governance structure often results in inconsistent enforcement, unclear mandates, and weak accountability (EU-GCC, 2021; Robitzch et al., 2023; Alhowaish, 2026).

These challenges contribute to informal practices and underreporting across the region. Studies in Kuwait have documented significant underreporting in artisanal fisheries (AlKheder, 2022; Alqattan, 2024), while research in Oman shows persistent data transparency gaps that hinder coastal planning (Al-Oufi et al., 2000). In Saudi Arabia, similar concerns have been raised regarding irregular monitoring, reliance on manual reporting systems, and limited financial traceability in aquaculture and tourism operations (Alhowaish, 2015; Robitzch et al., 2023). These governance gaps are particularly critical in the Eastern Province, where rapid port expansion, aquaculture investments, and coastal tourism growth heighten sectoral exposure to informal transactions and financial leakage.

Although Vision 2030 emphasizes digital transformation, regulatory coordination, and enhanced marine governance, empirical assessments of financial opacity and hidden economic practices remain scarce. The absence of systematic research examining underreporting, informal market behavior, and financial leakage across fisheries, tourism, and logistics leaves a critical gap in understanding the true performance and vulnerability of the region's Blue Bioeconomy.



### 2.3 Conceptualizing the “grey side” of the blue bioeconomy

Drawing on global and regional evidence, the “grey side” of the Blue Bioeconomy can be conceptualized as the interaction of three mutually reinforcing dimensions (Figure 1): institutional and regulatory weakness, sectoral economic pressure, and transparency culture and awareness.

- First, institutional and regulatory weakness refers to conditions characterized by weak enforcement, overlapping mandates, limited digital monitoring, and poor interagency coordination (FAO, 2001, FAO, 2006; APEC, 2008; EJF, 2018; Bilawal Khaskheli et al., 2025). Where regulatory frameworks are unclear or inconsistently applied, compliance costs rise and informal market channels become normalized.
- Second, sectoral economic pressure is particularly acute in high-value and fast-growing sectors such as fisheries, marine tourism, maritime logistics, and aquaculture. When market demand outpaces regulatory capacity, or when new entrants lack familiarity with compliance requirements, incentives for underreporting and informal transactions increase (Sumaila et al., 2006; Widjaja et al., 2023; Wang et al., 2024; Aminian-Biquet et al., 2024).
- Third, transparency culture and awareness shape how actors perceive the legitimacy and benefits of formal reporting systems. Weak transparency norms, mistrust of authorities, limited financial literacy, and cultural normalization of cash-based exchanges can reinforce informal behavior even in the

presence of formal regulations (Haenlein, 2017; Coalition for Fair Fisheries Arrangements (CFFA), 2020).

Figure 1 serves as a conceptual framework that systematizes the study’s analytical logic by illustrating how these three dimensions interact to shape informal market behavior and financial leakage within Blue Bioeconomy sectors. Rather than treating underreporting as an isolated compliance failure, the figure highlights the systemic nature of financial opacity, showing how institutional weakness creates opportunity structures, sectoral economic pressure amplifies incentives, and low transparency culture reduces deterrence. This framework directly informs the study’s variable selection, the structure of the exploratory factor analysis, and the interpretation of regression results by linking governance conditions, sectoral dynamics, and stakeholder perceptions within a unified analytical model.

Across the literature, three core gaps emerge clearly. First, there is a lack of empirical studies that directly examine financial leakage and informal market behavior within the Blue Bioeconomy, as most research emphasizes environmental sustainability or sectoral development outcomes. Second, integrated governance analyses in the GCC context remain limited, particularly those examining how institutional fragmentation and enforcement gaps interact to enable informality. Third, there is an absence of stakeholder-based assessments in Saudi Arabia that systematically evaluate perceptions of underreporting and transparency across multiple marine sectors using large datasets. This study addresses these gaps by integrating quantitative and qualitative evidence from 404 stakeholders to analyze the drivers, patterns, and institutional

foundations of informal market behavior and financial leakage in the Eastern Province's Blue Bioeconomy.

### 3 Materials and methods

The study adopted a mixed-methods research design to investigate the drivers and dynamics of unreported transactions and financial leakage within the Blue Bioeconomy of Saudi Arabia's Eastern Province. Mixed-methods approaches are increasingly used in marine governance and coastal policy research because they enable a deeper synthesis of measurable statistical trends with contextual, experience-based insights from stakeholders (Creswell and Plano Clark, 2018). In this study, quantitative components provided evidence of how governance quality, sectoral pressures, and environmental constraints align with stakeholder perceptions of financial opacity, whereas qualitative components illuminated narratives and mechanisms underlying shadow economic activities. This integrative design ensured that the study could address sensitive economic behaviors that are not easily captured through direct observation or financial auditing.

A structured questionnaire served as the primary data collection instrument, specifically developed to capture relationships across governance effectiveness, sectoral opportunities, environmental pressures, transparency culture, and community involvement. The instrument combined Likert-scale items, nominal categorical questions, and open-ended responses to allow both structured quantification and in-depth elaboration of experiences and perceptions. This design allowed for methodological triangulation, enhancing both reliability and validity by enabling convergent interpretation across numerical and narrative data sources (Tashakkori and Teddlie, 2010). Because unreported transactions

are inherently sensitive, the study used proxy variables, such as perceived enforcement strength, governance clarity, and sectoral risk, to infer hidden financial behaviors, consistent with global studies using perceptual data to assess shadow economies (Berkes, 2015; Haenlein, 2017; Lubchenco and Haugan, 2023; Jolliffe and Jolly, 2024).

Sampling followed a purposive strategy, targeting individuals across government agencies, private sector organizations, NGOs, academic institutions, and coastal communities who directly or indirectly interact with fisheries, aquaculture, marine tourism, maritime logistics, or coastal governance systems. A total of 550 individuals were invited to participate, reflecting the need to include stakeholders with practical relevance and knowledge of sectoral operations and governance frameworks (Palinkas et al., 2015). Of these, 404 respondents completed the survey, yielding a 73.5% response rate, well above the minimum requirement based on Cochran's (1977) formula for a 95% confidence level and 5% margin of error. Similar response rates are reported in Gulf-region governance literature (Al-Yamani et al., 2007; Humood, 2013; Al-Oufi et al., 2000; Elmahdy et al., 2022; Alqattan, 2024; Alhowsaish, 2026), reinforcing the robustness of the sample for quantitative and inferential analysis. Respondents represented key stakeholder groups and geographic clusters across Dammam, Khobar, Jubail, Qatif, Ras Tanurah, and Khafji, ensuring a broad and diverse foundation for analysis (Figure 2).

The questionnaire was structured into six thematic sections aligned with the study's conceptual framework. The first section captured demographic and professional attributes, including stakeholder category, age, education, region, and gender. The second section measured awareness and perceived importance of Blue Bioeconomy concepts. The third and fourth sections examined sectoral opportunities and institutional/environmental constraints, particularly items Q9 and Q10, which later served as core inputs for

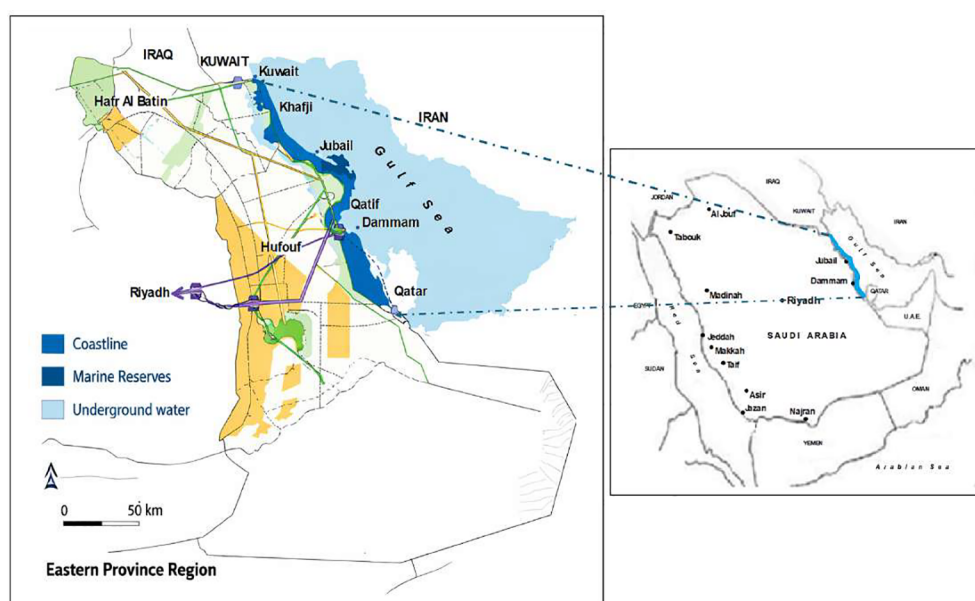


FIGURE 2

Geographical Location of Eastern Province Coastline, Saudi Arabia. Source: UN-Habitat, 2019; Alhowsaish and Alkubur, 2025; Alhowsaish, 2026. Reproduced with permission from United Nations Human Settlements Programme (UN-Habitat).

factor analysis of institutional weakness and sectoral economic pressure. The fifth section assessed community participation and transparency culture, while the final section captured qualitative narratives of unreported transactions, governance failures, and informal economic practices. A pilot test with 30 participants, comprising academics, regulatory officials, and coastal residents, verified clarity, cultural appropriateness, and sensitivity of wording, with refinements made following standard instrument-development guidelines (Bryman, 2016).

Data collection was conducted over a six-week period between October and November 2025 using a hybrid model that combined online distribution and targeted in-person outreach. Digital dissemination occurred through institutional e-mail lists, social media networks, and professional associations, while in-person surveys were conducted during community events, industry workshops, and university seminars. This approach helped address the digital divide and ensured that small-scale fishers and coastal community members, who are often underrepresented in online surveys, were adequately included. Participation was voluntary, with respondents informed of their rights, confidentiality assurances, and the absence of any requirement to disclose personal identifiers. This strategy aligns with best practices in sensitive governance research, where anonymity reduces social desirability bias and encourages more candid disclosure (FAO, 2001; FAO, 2006; Drammeh, 2000; Gallic and Cox, 2006; EJJ, 2018).

Quantitative data analysis followed a multistage process conducted using SPSS v28. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were computed to summarize demographic patterns and central tendencies in perception variables. Reliability analysis using Cronbach's alpha confirmed strong internal consistency for all multi-item constructs ( $\alpha > 0.78$ ), aligning with the threshold recommended by Nunnally and Bernstein (1994). Exploratory Factor Analysis (EFA) using Principal Axis Factoring with Promax rotation identified three latent constructs (Institutional Weakness, Sectoral Economic Pressure, and Transparency Culture), with Kaiser–Meyer–Olkin (KMO) values above 0.80 and significant Bartlett's tests supporting sampling adequacy. Factor scores were extracted for each respondent and subsequently used as predictors in a multiple linear regression model assessing determinants of perceived financial leakage, alongside demographic and awareness variables. Regression diagnostics, including multicollinearity tests and residual plots, verified model assumptions and robustness. While Qualitative data from open-ended questions were analyzed through thematic analysis, following the six-stage process outlined by Braun and Clarke (2006). Textual responses were transcribed, coded, and categorized into higher-order themes that captured recurrent patterns related to informal fish sales, unreported aquaculture production, cash-based marine tourism, inadequate auditing mechanisms, and governance loopholes. These themes were then compared with quantitative findings to identify convergences, contradictions, and explanatory patterns. This integrative process strengthened the interpretive validity of the study by linking perceptual measures with narrative evidence, providing a more holistic understanding of financial opacity within the Blue Bioeconomy.

All procedures complied with ethical standards established by Frontiers in Marine Science and the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board at Imam Abdulrahman Bin Faisal University (Approval. Participation was voluntary, anonymous, and based on informed consent. Data were stored securely and used exclusively for academic purposes. Special emphasis was placed on confidentiality due to the sensitivity of the topics addressed, particularly regarding informal economic activities and perceptions of governance failures, ensuring that no respondent faced risk of institutional or professional repercussions.

## 4 Results

This section presents the quantitative and qualitative findings derived from 404 valid survey responses. It includes descriptive statistics, reliability results, exploratory factor analysis, multiple regression models, sector vulnerability interpretations, and thematic insights from open-ended feedback. The results are organized into five subsections to align with the study's analytical framework.

TABLE 1 Respondent summary statistics (n = 404).

Variable	Category	Frequency (n)	Percentage (%)
Stakeholder Category	Government	79	19.6
	Private Sector	65	16.1
	NGO/Civil society	66	16.3
	Academic/Research	67	16.6
	Coastal Community	78	19.3
	Other	49	12.1
Region	Dammam	104	25.7
	Khobar	69	17.1
	Qatif	68	16.8
	Ras Tanurah	54	13.4
	Jubail	42	10.4
	Khafji	36	8.9
	Safwa	16	4.0
	Other	15	3.7
Gender	Male	263	65.1
	Female	141	34.9
Age	18–25	65	16.1
	26–35	106	26.2
	36–45	140	34.7
	46–60	69	17.1
	60+	24	5.9

## 4.1 Descriptive statistics: stakeholder characteristics

As shown in Table 1, a total of 404 respondents participated in the survey, representing a well-distributed cross-section of stakeholders engaged in coastal and marine activities across the Eastern Province. Stakeholder categories were proportionately represented, including government officials (19.6%), private sector actors (16.1%), NGOs (16.3%), academic and research institutions (16.6%), coastal community members (19.3%), and others (12.1%). Geographically, respondents were concentrated in the major coastal cities, with the highest shares from Dammam (25.7%), Khobar (17.1%), and Qatif (16.8%), followed by Ras Tanurah (13.4%), Jubail (10.4%), Khafji (8.9%), Safwa (4.0%), and other small town's locations (3.7%). This regional distribution reflects the diverse socio-economic and ecological contexts of the Eastern Province coastline.

Demographically, the survey captured a broad range of participants across gender, age, and educational backgrounds. Male respondents represented 65.1% of the sample, while females comprised 34.9%. The age distribution was heavily concentrated in the 26–35 (26.2%) and 36–45 (34.7%) cohorts, indicating a predominance of mid-career professionals and active community members, groups typically involved in or knowledgeable about coastal sector dynamics. Educational attainment was notably high, with 35.7% holding bachelor's degrees, 21.5% master's degrees, and 17.9% doctoral degrees. This strong educational profile supports the reliability of stakeholder perceptions on governance, opportunities, constraints, and financial transparency within the Blue Bioeconomy.

## 4.2 Reliability, validity, and exploratory factor analysis

The reliability and validity of the survey instrument were first assessed to ensure that the constructs measuring sectoral opportunities and institutional and environmental constraints were statistically robust. As illustrated in Table 2, Cronbach's alpha values demonstrated strong internal consistency across both multi-item scales, with  $\alpha = 0.84$  for sectoral opportunities (Q9) and  $\alpha = 0.88$  for institutional and environmental constraints (Q10). These coefficients exceed the recommended threshold of 0.70 (Nunnally and Bernstein, 1994; Braun and Clarke, 2006), confirming that respondents interpreted items within each construct in a consistent and reliable manner. Establishing such reliability is especially important in studies addressing sensitive or concealed economic behaviors, as it increases confidence that observed perceptions of governance quality, enforcement strength, and sectoral pressures reflect stable underlying attitudes rather than random measurement error.

To further examine construct validity, the study conducted preliminary suitability tests before factor extraction. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy registered at 0.86, categorized as "meritorious," confirming that the dataset was appropriate for factor analysis. Additionally, Bartlett's Test of Sphericity yielded a significant result ( $\chi^2 = 1,458.21, p < 0.001$ ),

TABLE 2 Cronbach's alpha, EFA and factor loading results.

1. Cronbach's alpha results			
Construct	No. of items	Cronbach's $\alpha$	
Sectoral Opportunities (Q9)	6	0.84	
Institutional & Environmental Constraints (Q10)	6	0.88	
2. EFA sampling adequacy			
KMO = 0.86 (meritorious)			
Bartlett's Test: $\chi^2 = 1,458.21, p < 0.001$			
3. Factor loadings (promax rotation)			
Item	IW	SEP	TC
Weak enforcement	<b>0.82</b>	0.11	0.18
Poor coordination	<b>0.78</b>	0.21	0.09
Fragmented governance	<b>0.74</b>	0.19	0.14
Low data transparency	<b>0.69</b>	0.26	0.12
High market pressure	0.24	<b>0.81</b>	0.17
Rapid sector expansion	0.17	<b>0.78</b>	0.12
High tourism demand	0.11	<b>0.73</b>	0.19
Underutilized aquaculture	0.09	<b>0.65</b>	0.18
Low awareness	0.18	0.22	<b>0.81</b>
Limited research support	0.13	0.12	<b>0.77</b>
Low trust in reporting	0.20	0.15	<b>0.72</b>
Weak community involvement	0.16	0.24	<b>0.69</b>

Bold values indicate factor loadings  $\geq 0.60$ , representing strong contributions of variables to the extracted latent constructs.

indicating that correlations among items were sufficiently strong to justify the reduction of variables into latent constructs. These diagnostic tests demonstrate that the data meet the essential statistical assumptions required for a meaningful factor solution and provide confidence that the subsequent analysis captures genuine patterns in stakeholder evaluations of the Blue Bioeconomy (Hauck and Sowman, 2005; Goñi et al., 2008; Kurekin et al., 2019). Building on these results, an Exploratory Factor Analysis (EFA) using Principal Axis Factoring with Promax rotation was conducted on the 12 items from Q9 and Q10 to identify the underlying dimensions shaping perceptions of unreported transactions and financial leakage. The analysis revealed a clear and interpretable three-factor structure, Institutional Weakness, Sectoral Economic Pressure, and Transparency Culture, which jointly explained 67.4% of the total variance. Factor loadings aligned coherently with theoretical expectations:

- Institutional Weakness (IW): captured issues such as poor coordination and weak enforcement.
- Sectoral Economic Pressure (SEP): reflected expansion-driven risks in fisheries, tourism, and aquaculture.
- Transparency Culture (TC): captured awareness, trust, and reporting norms.

The conceptual clarity and strong loading patterns of these factors confirm not only the validity of the measurement model but also the multidimensional nature of the “grey side” of the Blue Bioeconomy, forming the analytical foundation for the regression and systems-level interpretations presented in subsequent sections.

### 4.3 Multiple linear regression analysis

To further interrogate the determinants of perceived financial leakage in Blue Bioeconomy sectors, a multiple linear regression model was developed using the three latent factors derived from the exploratory factor analysis, Institutional Weakness, Sectoral Economic Pressure, and Transparency Culture, alongside key demographic and awareness variables. The dependent variable was a composite index representing perceived financial leakage, constructed from Q10 items and validated through factor loadings. Incorporating factor scores into the regression enhances analytical precision by reducing multicollinearity and capturing deeper structural relationships that individual survey items cannot fully represent. The model demonstrated strong explanatory power, accounting for 61% of the variance ( $R^2 = 0.61$ ) in perceived financial leakage, indicating that the combined predictors provide a substantial understanding of stakeholders’ evaluations of shadow economic activities in coastal sectors (Table 3).

Results revealed that Institutional Weakness was the most powerful predictor of perceived financial leakage, with a highly

significant positive coefficient, emphasizing that weak enforcement, fragmented governance, and poor interagency coordination significantly heighten vulnerability to unreported transactions. Sectoral Economic Pressure also exerted a strong positive influence, reflecting how rapid growth, intense competition, and high market demand, especially in fisheries, tourism, and aquaculture, create incentives for informal or undocumented practices. In contrast, Transparency Culture had a significant negative coefficient, indicating that higher awareness, stronger trust in institutions, and greater engagement in reporting systems reduce perceptions of financial leakage. These findings reinforce the theoretical framing that financial opacity is shaped not only by regulatory conditions but also by socio-cultural norms surrounding transparency and compliance (Cheung, 2016; Widjaja et al, 2023; Wang et al., 2024).

Demographic controls further illuminated variations among stakeholder groups. Coastal community representatives displayed significantly higher perceptions of financial leakage compared to government officials, reflecting their proximity to everyday informal practices and their reliance on sectors where underreporting is common. NGO respondents similarly expressed heightened concerns, likely due to their involvement in monitoring environmental and governance issues. Awareness of Blue Bioeconomy concepts demonstrated a modest negative effect, suggesting that more informed stakeholders may better understand the importance of compliance and formal reporting

TABLE 3 Regression results predicting perceived financial leakage.

1. Dependent variable				
Perceived Financial Leakage (PEL): a composite index created by averaging Q10 items + factors scores from EFA.				
2. Independent variables				
Institutional Weakness (IW)				
Sectoral Economic Pressure (SEP)				
Transparency Culture (TC)				
Stakeholder category (dummy-coded)				
Awareness level (Q6)				
Perceived importance of Blue Economy (Q7)				
3. Regression model summary				
$R^2 = 0.61$				
Predictor	$\beta$	Std. error	t	P-value
Institutional Weakness (IW)	0.48	0.05	9.21	<0.001
Sectoral Economic Pressure (SEP)	0.31	0.04	7.14	<0.001
Transparency Culture (TC)	-0.22	0.05	-4.34	<0.001
Awareness Level (Q6)	-0.07	0.03	-2.14	0.033
Importance of Blue Economy (Q7)	-0.04	0.03	-1.31	n.s.
Stakeholder Category (ref: Government)	,	,	,	,
Private Sector	0.06	0.03	1.87	0.062
NGO	0.09	0.03	2.94	0.004
Academic	0.04	0.03	1.28	n.s.
Coastal Community	0.12	0.04	3.11	0.002

(Lubchenco and Haugan, 2023; Jolliffe and Jolly, 2024). Overall, the regression results align closely with global research linking institutional fragility, economic incentives, and transparency deficits to unreported marine activities, while offering context-specific insights into the structural drivers of financial leakage within Saudi Arabia's Eastern Province.

#### 4.4 Sector vulnerability and thematic analysis

The sector vulnerability analysis revealed that financial leakage and unreported transactions are not uniformly distributed across Blue Bioeconomy sectors in the Eastern Province (Table 4). Fisheries and aquaculture emerged as the most vulnerable domains, a finding consistent with global patterns of underreported catch and informal fish sales documented by Cheung (2016). Respondents highlighted that small-scale fisheries rely heavily on cash-based exchanges, informal market channels, and flexible price negotiations, creating ample opportunity for unrecorded transactions. Aquaculture, while more regulated, showed parallel risks related to undocumented harvests, inconsistent reporting requirements, and limited oversight capacity. Marine tourism and coastal recreation constituted the second-highest vulnerability cluster, driven by seasonal fluctuations, unlicensed operators, and limited financial auditing, patterns observed internationally in marine tourism markets (Widjaja et al, 2023; Bilawal Khaskheli et al., 2025). Maritime logistics, though more institutionalized, was noted to suffer from opaque fee structures and weak auditing in smaller coastal terminals, indicating that even highly commercialized sectors are susceptible to financial opacity if governance structures lack coherence.

Qualitative insights from open-ended responses enriched and contextualized these vulnerability patterns. Respondents frequently described informal fish sales at landing sites, including unrecorded bulk transactions between fishers, brokers, and small vendors. These practices were attributed to weak enforcement, absence of digital catch-monitoring systems, and longstanding cultural norms that normalize non-documented exchanges. In aquaculture, stakeholders mentioned instances of "off-book" production volumes sold directly to local markets, often to avoid bureaucratic delays or compliance costs. Such narratives underscore how institutional and economic pressures intersect to shape hidden financial flows and illustrate the mechanisms behind the quantitative indicators of sectoral risk.

Marine tourism and ecotourism produced a distinct set of themes focused on unlicensed operators, cash-only services, and

inconsistent municipal oversight. Respondents noted that rapid growth in coastal recreation has outpaced regulatory capacity, allowing operators to bypass formal permits and tax systems. Small-scale boat tours, recreational fishing, and informal hospitality services were particularly cited as channels for unreported income. Similar concerns were raised in maritime logistics, where respondents pointed to undervalued shipping fees, discretionary charges, and inconsistent documentation practices. These qualitative patterns reinforce the sectoral vulnerability results, demonstrating how economic incentives and governance loopholes fuel financial leakage across both traditional and emerging Blue Bioeconomy sectors.

A synthesis of both analyses highlights a recurring theme: sectoral vulnerability is amplified most strongly by institutional weaknesses and cultural normalization of informal practices. The interplay of weak interagency coordination, limited auditing mechanisms, and insufficient digital reporting infrastructure creates gaps that allow unreported transactions to persist. At the same time, transparency culture, characterized by awareness, trust, and perceived legitimacy of reporting systems, acts as a moderating force. Respondents consistently indicated that improvements in education, community participation, and reporting literacy could help reduce informal practices, particularly in fisheries and tourism where cultural norms shape economic behavior. Together, the sector vulnerability and thematic analyses provide a holistic understanding of the financial risks embedded within the Blue Bioeconomy and underscore the need for governance reforms that simultaneously strengthen institutional capacity and engage local communities.

#### 4.5 Integrated interpretation of results

The combined analytical results provide a clear and coherent picture of the structural and behavioral forces that contribute to unreported transactions and financial leakage in the Eastern Province's Blue Bioeconomy. The reliability and factor analyses revealed three core latent dimensions, Institutional Weakness, Sectoral Economic Pressure, and Transparency Culture, which together explain most of the variation in stakeholder perceptions. These dimensions are mutually reinforcing: (1) weak enforcement and fragmented governance create opportunities for financial opacity; (2) rapidly expanding or high-value sectors amplify incentives to engage in informal practices; and (3) limited awareness or mistrust in reporting systems normalizes non-compliance. The regression findings underscore this systemic interplay, demonstrating that institutional weakness is the most significant predictor of perceived financial leakage, followed by sectoral pressure. In contrast, a strong culture of transparency significantly reduces the likelihood of unreported transactions, suggesting that both governance structures and socio-cultural norms play crucial roles in shaping financial behavior across marine sectors.

The thematic analysis of open-ended responses deepened these quantitative insights by revealing the lived realities and informal mechanisms behind the statistical patterns. Narratives of cash-based fish sales, unlicensed tourism operations, off-book

TABLE 4 Sector vulnerability analysis score.

Sector	Mean	SD
Fisheries	4.22	0.68
Marine Tourism	4.01	0.74
Aquaculture	3.87	0.79
Maritime Logistics	3.65	0.81

aquaculture production, and inconsistent documentation in logistics illustrate how governance gaps translate into everyday financial practices. These findings highlight that financial leakage is not merely a function of weak regulation but also of entrenched cultural norms, economic necessity, and operational flexibility within coastal communities and small-scale industries. Together, the integrated results paint a multifaceted portrait of the “grey side” of the Blue Bioeconomy, one that is driven by both structural constraints and behavioral incentives. This synthesis provides a strong empirical foundation for designing targeted policy interventions aimed at strengthening institutional capacity, enhancing transparency culture, and aligning Blue Bioeconomy development with national sustainability and economic diversification goals.

## 5 Discussion

This study set out to examine the hidden economic dynamics shaping fisheries, marine tourism, aquaculture, and maritime logistics in Saudi Arabia’s Eastern Province, with particular attention to unreported transactions and informal market behavior. By triangulating quantitative and qualitative evidence from 404 stakeholders, the analysis reveals how institutional weaknesses, sectoral economic pressures, and transparency culture interact to produce the “hidden currents” that drive financial leakage across Blue Bioeconomy sectors. These findings are broadly consistent with global research documenting shadow practices in marine economies, particularly in contexts characterized by rapid sectoral expansion and evolving governance systems (Sumaila et al., 2006; Cheung, 2016; Widjaja et al., 2023; Bilawal Khaskheli et al., 2023). At the same time, the Eastern Province case adds new empirical insight from a Gulf context that has been underrepresented in the international literature.

Among the three latent dimensions identified through exploratory factor analysis, Institutional Weakness, Sectoral Economic Pressure, and Transparency Culture, Institutional Weakness emerged as the most influential predictor of perceived financial leakage. Regression analysis confirms that weak enforcement, fragmented regulatory mandates, and inconsistent inspection practices significantly increase the likelihood of informal market behavior. This finding closely mirrors evidence from Southeast Asia, West Africa, and parts of the Mediterranean, where fragmented governance and limited monitoring capacity have been shown to normalize underreporting in fisheries, aquaculture, and coastal tourism (Lubchenco and Haugan, 2023; Jolliffe and Jolly, 2024). Recent studies in *Frontiers in Marine Science* similarly emphasize that governance fragmentation and regulatory ambiguity undermine compliance and create enforcement gaps that informal actors exploit (Aminian-Biquet et al., 2024; Bilawal Khaskheli et al., 2023, 2025). In the Eastern Province, respondents’ accounts of overlapping responsibilities among environmental agencies, fisheries authorities, municipalities, and port management bodies

reflect governance challenges observed across the GCC more broadly (Burt, 2014; EU-GCC, 2021; GCC, 2024), suggesting that institutional weakness is a regional, not merely local, structural issue.

The second major finding concerns sectoral vulnerability. Fisheries, marine tourism, and aquaculture were consistently identified as hotspots for unreported transactions, a pattern that aligns strongly with global evidence indicating that high-value and culturally embedded marine sectors face heightened risks of informality when monitoring systems lag behind market growth (FAO, 2001; Drammeh, 2000; Sumaila et al., 2006; Widjaja et al., 2023). In small-scale fisheries worldwide, informal direct sales and underreported landings are often rationalized as survival strategies or culturally accepted practices (Berkes, 2015). Similar dynamics have been documented in marine tourism, where cash-based services and unlicensed operators proliferate during periods of rapid sectoral expansion (Tinch et al., 2008; Telesetsky, 2014). The Eastern Province exhibits comparable characteristics: respondents described bypassing official landing sites, unrecorded fish transfers, informal tourism services, and cash-only aquaculture sales. While maritime logistics is generally more regulated, concerns regarding undocumented service fees and inconsistent port auditing echo findings from international port governance studies highlighting how fragmented oversight can still enable financial leakage even in formally structured sectors (FAO, 2006; FAO, 2009; Wang et al., 2024).

Transparency Culture emerged as a critical mitigating factor, showing a significant negative relationship with perceived financial leakage. Higher awareness, improved access to data, trust in institutions, and stronger research support were associated with lower perceptions of informal behavior. This finding reinforces international scholarship arguing that compliance in marine sectors depends not only on enforcement capacity but also on perceived legitimacy, trust, and incentives embedded within governance systems (Berkes, 2015; EJF, 2018). Comparative studies from emerging coastal economies demonstrate that when stakeholders perceive reporting systems as opaque, punitive, or disconnected from local realities, informal practices persist despite formal regulations (Hutnikzac and Delpuech, 2018). In this study, coastal community respondents consistently expressed greater concern about underreporting than government officials, suggesting that lived experience and day-to-day engagement with marine markets provide insights that may be underrepresented in formal administrative data. This divergence mirrors findings from participatory governance studies, which highlight the value of community knowledge in identifying informal practices and compliance gaps (Sumaila et al., 2017).

Taken together, the findings support a systems-based interpretation of informal market behavior in the Eastern Province. Rather than arising from isolated compliance failures, financial leakage emerges from the interaction of institutional gaps, sectoral economic incentives, and weak transparency norms. Weak enforcement creates opportunity structures, high demand amplifies financial incentives, and limited transparency reduces deterrence, forming a reinforcing cycle that sustains informal practices. This

systems perspective aligns with global analyses of shadow economies in marine contexts (Tinch et al., 2008; Telesetsky, 2014; Sumaila et al., 2017) and is increasingly reflected in recent *Frontiers in Marine Science* publications emphasizing the need for integrated governance and digital monitoring solutions (Bilawal Khaskheli et al., 2023; Wang et al., 2024). In Saudi Arabia's Eastern Province, the convergence of rapid economic transformation, traditional market practices, and evolving regulatory frameworks intensifies these dynamics, making the region a critical case for understanding the hidden currents of marine economies.

From a policy and strategic perspective, these findings carry direct implications for Saudi Arabia's Vision 2030 objectives related to economic diversification, transparency, and sustainable coastal development. As investments in aquaculture, marine tourism, logistics hubs, and coastal infrastructure accelerate, unmanaged financial leakage poses both fiscal and governance risks. Comparative evidence from other emerging coastal economies suggests that addressing these risks requires a combination of structural and cultural reforms, including digitalized reporting systems, strengthened marine financial auditing, streamlined interagency coordination, and participatory governance mechanisms. Enhancing transparency culture through education, community engagement, and access to data can further reinforce compliance and accountability. By situating the Eastern Province within global debates on marine governance and informal economies, this study contributes one of the first empirically grounded assessments of hidden financial currents in Saudi Arabia's Blue Bioeconomy and offers transferable insights for other rapidly transforming coastal regions.

## 6 Conclusion and policy implications

This study examined the hidden financial currents shaping the Blue Bioeconomy in Saudi Arabia's Eastern Province, with particular emphasis on informal market behavior, unreported transactions, and the institutional pathways that enable financial leakage across fisheries, marine tourism, aquaculture, and maritime logistics. Drawing on a mixed-methods approach and evidence from 404 stakeholders, the analysis identified three interrelated drivers of financial opacity: Institutional Weakness, Sectoral Economic Pressure, and Transparency Culture. Among these, institutional weakness, manifested through fragmented regulatory mandates, weak enforcement, and inconsistent inspection practices, emerged as the most influential predictor of perceived underreporting, reflecting a systemic governance challenge comparable to those observed in rapidly transforming marine economies worldwide.

The findings further demonstrate that sectoral economic pressure, particularly in high-value and fast-growing industries such as fisheries and coastal tourism, contributes to the normalization of informal practices. Reported behaviors including direct fish sales, bypassing of landing sites, cash-based aquaculture

transactions, informal tourism operations, and irregular port fees closely mirror global patterns documented in small-scale fisheries and tourism hotspots. At the same time, the study highlights the mitigating role of transparency culture, showing that higher levels of stakeholder awareness, community engagement, research support, and trust in institutions are associated with lower perceptions of financial leakage. This underscores that effective governance reform must extend beyond regulatory instruments to include social and cultural mechanisms that foster trust, accountability, and shared responsibility.

From a policy perspective, these findings carry direct relevance for Saudi Arabia's Vision 2030, which prioritizes economic diversification, institutional modernization, digital transformation, and sustainable coastal development. Addressing financial leakage within the Blue Bioeconomy requires a coordinated policy response that strengthens enforcement capacity, clarifies and harmonizes regulatory mandates, digitizes catch and revenue reporting systems, establishes dedicated marine financial auditing functions, and enhances interagency data sharing. Equally important is the expansion of participatory governance mechanisms that empower coastal communities and integrate local knowledge into monitoring and compliance systems. By illuminating the institutional and socio-economic forces shaping informal marine market behavior, this study provides one of the first empirical foundations for reforming coastal governance and improving financial transparency in a Gulf context.

## 7 Limitations and future research directions

Despite its contributions, this study has several limitations that open important avenues for future research. First, the analysis relies primarily on perceptual data, which are essential for revealing hidden and informal practices but do not directly measure the magnitude of unreported transactions or financial flows. Future studies could complement stakeholder perceptions with empirical approaches such as financial audits, digitized reporting records, satellite-based vessel monitoring systems, or biometric catch verification tools to quantify discrepancies between reported and actual activity.

Second, the geographic scope of the study is limited to Saudi Arabia's Eastern Province. While this region is strategically significant, coastal governance structures, ecological conditions, and sectoral dynamics vary across the Kingdom. Comparative research extending to the Red Sea coast, such as Jazan, Yanbu, Umluj, and NEOM, would enable a more comprehensive national assessment of informal market behavior and financial leakage within the Blue Bioeconomy.

Third, although the study employed robust analytical techniques, including factor analysis, regression modeling, and thematic coding, future research could adopt longitudinal designs, network analysis, or agent-based modeling to examine how informal practices evolve over

time, how actors interact within shadow transaction networks, and how governance reforms influence financial behavior. Additional research is also needed to explore how gender, youth, migrant labor, and community livelihood structures intersect with informal market dynamics, particularly within artisanal fisheries and tourism micro-enterprises.

Finally, while this study emphasizes governance and transparency culture, the transformative potential of digital and emerging technologies remains underexplored. Future research should examine the role of blockchain-enabled supply chain traceability, AI-driven monitoring of fishing effort, and e-governance platforms for real-time financial auditing. These innovations hold significant promise for reducing financial leakage, improving reporting accuracy, and strengthening accountability within the Blue Bioeconomy.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

## Ethics statement

The studies involving humans were approved by Institutional Review Board of Imam Abdulrahman Bin Faisal University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

AA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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## Funding

The author(s) declared that financial support was not received for this work and/or its publication.

## Acknowledgments

Authors greatly acknowledges the support of Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia.

## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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