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# Blue Biotechnology Startups in Bangladesh: An Empirical Evidence on Opportunities Barriers, and Pathways Forward

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## ABSTRACT

The global blue biotechnology sector, projected to exceed $10 trillion by 2030 through marine-derived pharmaceuticals, nutraceuticals, and sustainable aquaculture innovations, represents an unprecedented economic frontier that Bangladesh, endowed with 118,813 km² of exclusive economic zone and unparalleled Bay of Bengal biodiversity, remains uniquely positioned to capture through strategic startup ecosystem development. This pioneering study employs a quantitative cross-sectional survey (N=223) targeting Bangladesh's blue biotechnology stakeholders, revealing a significant paradox: 93.3% exhibit entrepreneurial fervor, yet 75.3% perceive an investment crisis as the most existential operational threat, while 96.9% affirm the sector's viability, despite 59.2% acknowledging knowledge deficits. Chi-square analyses ($p < .001$) reveal age-stratified challenge perceptions, with youth decrying government support voids, mid-career professionals' infrastructure chasms, and gender-differentiated opportunity lenses. Males prioritize seafood demand (43.4%), while females focus on raw material abundance (28.1%). Marine natural products (39.9%) and aquaculture biotech (31.4%) emerge as consensus research priorities; however, a 40-point intention-investment chasm (93% vs. 53%) signals a capital ecosystem failure. Universal endorsement (100%) of university-industry symbiosis demands immediate institutionalization. This research fills the academic void on blue biotech entrepreneurship in developing countries, delivering battle-tested policy instruments: patient-capital venture funds, shared marine biobanks, formalized tech-transfer pipelines, and hybrid business models that fuse domestic aquaculture scaling with global pharma licensing. Bangladesh confronts a binary future: squander a trillion-dollar marine inheritance through inaction, or architect a blue biotech supernova catalyzing 21st-century economic transcendence. The empirical clarion call: convert 93% entrepreneurial fire into a $10B+ GDP alchemy through the ruthless execution of the knowledge-capital-infrastructure triad.

## INTRODUCTION

Blue biotechnology, broadly defined as the use of marine bioresources and associated biotechnological tools to develop products and services for sectors such as pharmaceuticals, food, aquaculture, cosmetics, and environmental remediation, has emerged over the past two decades as a distinctive and promising pillar of the global bioeconomy (Collins *et al.,* 2018; OECD, 2013). The oceans cover more than 70% of the Earth's surface and host an extraordinary proportion of global biodiversity; 34 of 36 known animal phyla occur in the marine environment, making marine ecosystems an unparalleled reservoir of structurally novel and biologically active molecules that can underpin new high-value innovations (Arrieta *et al.,* 2010; Collins *et al.,* 2018). Recent market analyses suggest that the global marine or blue biotechnology sector, while still relatively small compared with red or green biotechnology, has grown steadily and was projected to reach approximately USD 4.8 billion in annual revenues by 2020, with compound annual growth rates estimated in the range of 4–12% depending on underlying assumptions and segment definitions (European Commission, 2014; Global Industry Analysts, Inc., 2025; OECD, 2013). Within this global context, small and medium-sized enterprises (SMEs) and startups play a critical bridging role between upstream discovery in universities or public research organizations and downstream industrial up-scaling and commercialization, particularly in application areas such as marine-derived pharmaceuticals, enzymes, nutraceuticals and biomaterials; however, these firms typically operate in the high-risk, "cash burn" portion of the value chain where substantial upfront investment is required long before revenues can be generated, exposing them acutely to financing constraints, technological uncertainty and regulatory complexity (European Commission, 2014; Tölle & Herbst, 2016; Querellou, 2010). More generally, the entrepreneurship literature has consistently documented that startups across sectors face high failure rates often estimated at 70–90% in the first years of operation—due to a combination of internal factors such as limited managerial experience, weak teams, and immature business models, and external factors including access to finance, market volatility and policy or infrastructural deficits (Cantamessa *et al.,* 2018; Frese *et al.,* 2014; Ries, 2011). In biotechnology specifically, firms confront additional industry-specific challenges arising from long, costly and heavily regulated research



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and development (R&D) cycles, strong dependence on intellectual property, and the need to navigate clinical or regulatory approval pathways, which together can delay commercialization for a decade or more and make business model design particularly consequential (Tölle & Herbst, 2016; Pisano, 2006; Skvarka & Farkas, 2013). Empirical studies of biotech SMEs have shown that pharmaceutical-oriented startups tend to adopt research-centric models built around patents and milestone-driven partnerships, often with no product revenues for extended periods, whereas non-pharmaceutical biotech SMEs can sometimes pursue more customer-centric models with faster time-to-market, underscoring that sectoral positioning within biotechnology shapes both opportunity structures and risk profiles (Tölle & Herbst, 2016; Nosella *et al.,* 2005). At the same time, work on innovation ecosystems suggests that the success of knowledge-intensive startups depends not only on firm-level capabilities but also on the quality of the surrounding "quadruple helix" configuration connecting academia, industry, government and civil society, including the availability of specialized infrastructure (e.g., marine stations, biobanks, wet labs), incubators and accelerators, coherent regulatory frameworks, and targeted financial instruments (Carayannis & Campbell, 2009; Spigel, 2017). Bangladesh has recently articulated ambitions to harness the "blue economy" of the Bay of Bengal for sustainable development and economic diversification, and possesses significant marine biodiversity and a large coastal population engaged in fisheries and related activities, yet systematic analyses of how these natural and policy endowments translate into concrete opportunities and challenges for blue biotechnology startups remain conspicuously scarce in the academic literature (Hussain *et al.,* 2018; Islam & Shamsuddoha, 2018; Islam *et al.,* 2024). Existing studies on startups in developing and emerging economies, including South Asia, highlight pervasive constraints such as limited access to early-stage risk capital, weak intellectual property regimes, infrastructural deficits, and fragmented support ecosystems, which are likely to be even more salient in capital- and knowledge-intensive domains like biotechnology and marine innovation (Alvedalen & Boschma, 2017; Autio & Rannikko, 2016; Hyder & Lussier, 2016). Against this backdrop, there is a clear conceptual and empirical gap regarding how the generic success and failure factors identified in the broader startup and biotech entrepreneurship literatures intersect with the specific institutional, ecological and economic context of Bangladesh's emerging blue economy.

Synthesizing international evidence on blue biotechnology value chains, biotech SMEs' business models, and startup ecosystems with the nascent body of work on Bangladesh's marine and entrepreneurial development to examine the opportunities and challenges facing blue biotechnology startups in Bangladesh. By doing so, it contributes to an improved understanding of how a resource-rich but institutionally constrained coastal developing country can position itself to foster blue-biotech ventures capable of translating marine biodiversity into sustainable economic and societal benefits and offers policy and managerial implications for designing more enabling ecosystems for such startups.

## MATERIALS AND METHODS

### Research Design

This study employed a quantitative, cross-sectional survey research design to investigate awareness of blue biotechnology, perceived opportunities and challenges, and entrepreneurial intentions among potential stakeholders in Bangladesh (Creswell & Creswell, 2022). The cross-sectional approach facilitated systematic data collection at a single time point, allowing for the examination of relationships between demographic characteristics and attitudes toward blue biotechnology entrepreneurship (Bryman, 2016). Quantitative methodology was selected as the optimal approach for measuring awareness levels, opportunity assessments, barrier perceptions, and entrepreneurial intentions across a demographically diverse sample-constructs that require standardized measurement and statistical inference, rather than qualitative exploration (Fowler, 2014).

The research objectives necessitated capturing perspectives from individuals positioned to participate in or support Bangladesh's emerging blue biotechnology ecosystem, including students in relevant disciplines, academic researchers, government officials, private sector professionals, and current or aspiring entrepreneurs. Given the sector's nascent state and absence of established blue biotechnology firms in Bangladesh, the study focused on potential rather than current participants, assessing readiness, knowledge gaps, and perceived barriers that would shape future ecosystem development.

### Population and Sampling Strategy

The target population consisted of individuals with educational backgrounds, occupational roles, or interests relevant to the development of blue biotechnology and the blue economy in Bangladesh. This encompassed university students in science, biotechnology, marine science, business, and related fields; academics and researchers in relevant disciplines; government employees involved in marine resource management, environmental policy, or economic development; private sector professionals in aquaculture, pharmaceuticals, environmental services, or related industries; and individuals with entrepreneurial interests or experience.

Given the absence of a comprehensive sampling frame listing all potential blue biotechnology stakeholders in Bangladesh, non-probability purposive sampling was employed (Etikan *et al.,* 2016). Purposive sampling enabled targeted recruitment of respondents possessing relevant knowledge, educational credentials, or professional experience to provide informed perspectives on blue economy concepts and biotechnology entrepreneurship (Palinkas *et al.,* 2015). This approach proved appropriate for exploratory research examining an emerging sector where the relevant population lacks clear boundaries and systematic enumeration.

Inclusion criteria required that respondents: (1) be at least 18 years of age; (2) reside in Bangladesh; and (3) possess a minimum higher secondary education or equivalent qualification. The educational threshold ensured sufficient foundational knowledge to comprehend survey items addressing biotechnology concepts, marine resource economics, and entrepreneurship frameworks. No exclusion criteria based on gender, occupation, prior exposure to the blue economy, or geographic location within Bangladesh were applied, as capturing diverse perspectives across demographic segments constituted a core research objective.

Sample size determination followed established guidelines for survey research employing chi-square and correlation analyses, which recommend minimum samples of 200–400 respondents for adequate statistical power in descriptive studies (Bartlett *et al.,* 2001; Cohen, 1992). The final sample comprised 223 valid responses, exceeding the minimum thresholds and providing sufficient power to detect moderate effect sizes (Cohen's $w = 0.30$) at $\alpha = 0.05$, with power exceeding 0.80 (Cohen, 1988). Data collection took place between January and March 2024, within a focused three-month window, to minimize temporal variation in awareness levels that might result from policy announcements, media coverage, or other time-varying influences.

**Survey Instrument Development**

Data were collected using a structured, self-administered questionnaire comprising closed-ended and Likert-scale items (DeVellis, 2016). The instrument was developed through a systematic literature review of blue economy frameworks, blue biotechnology applications, biotechnology entrepreneurship challenges, and startup ecosystem factors in developing country contexts (Hyder & Lussier, 2016; Querellou, 2010). Question formulation followed established survey design principles to ensure clarity, avoid leading or double-barreled items, employ mutually exclusive and exhaustive response categories, and minimize acquiescence and social desirability bias (Dillman *et al.,* 2014; Krosnick & Presser, 2010).

The questionnaire comprised six thematic sections totaling 35 items:

**Section 1: Demographic Characteristics**

Demographic Characteristics (4 items) captured gender, age (five categories: 18–24, 25–34, 35–44, 45–54, 55+), educational attainment (five ordinal levels: higher secondary, bachelor's, master's, doctoral, post-doctoral), and occupation (student, government job, private job, business person, others).

**Section 2: Blue Economy Awareness**

Blue Economy Awareness (7 items) assessed prior knowledge of blue economy concepts (yes/no), information sources (Facebook, Twitter, newspaper, journal, others), beliefs regarding sustainability potential (single item: all respondents affirmed belief), and self-reported understanding of ecosystem, climate change, and biodiversity conservation using three-point scales (good understanding / a little bit/nothing).

**Section 3: Blue Economy Interests and Entrepreneurial Intentions**

Blue Economy Interests and Entrepreneurial Intentions (12 items) explored content domain interests (natural capital conservation, economic growth, poverty alleviation, innovation), favorite sectors (fisheries/aquaculture, marine resource extraction, shipping, tourism, governance, biodiversity conservation), intentions to start blue economy ventures (yes/no), target audiences (everyone vs. specific), preferred exploration areas, anticipated competitors (inside vs. outside Bangladesh), marketing strategies (online vs. offline), pricing approaches, and agreement with statements regarding blue economy startup investment security and youth participation.

**Section 4: Blue Biotechnology Knowledge and Perceptions**

Blue Biotechnology Knowledge and Perceptions (8 items) measured familiarity using a four-point scale (very familiar / somewhat familiar / not very familiar / not at all familiar), beliefs about future prospects in Bangladesh (yes/no), work experience in the sector (yes/no), perceived opportunities (availability of raw materials, growing seafood demand, increasing awareness, favorable policies), ecological balance contributions, value perceptions of seaweed/biofuels/marine bioactive substances, and assessments of current biotech startup success in Bangladesh.

**Section 5: Ecosystem Support and Collaboration**

Ecosystem Support and Collaboration (4 items) evaluated importance of university-research institution collaboration (very important / somewhat important / not very important / not at all important), promising research areas (marine natural products, aquaculture biotechnology, marine genomics, bioremediation), investment likelihood (very likely / somewhat likely / not very likely / not at all likely), and investment decision factors (management team quality, innovation level, market size potential).

**Section 6: Challenges and Barriers**

Challenges and Barriers (4 items) identified biggest challenges facing blue biotechnology startups (lack of funding, lack of skilled workforce, lack of infrastructure, lack of government support), operational challenges expected most frequently (investment crisis, maritime law, admiralty law), agreement that blue biotechnology has potential to provide food/medication if properly used, and support for Bangladesh adopting strategies similar to developed countries.

The instrument underwent pilot testing with 15 individuals representing target population demographics prior to full deployment (Presser *et al.,* 2004). Pilot participants completed the survey and provided feedback on the clarity of questions, appropriateness of response categories, completion time, and technical functionality. Minor refinements to wording and ordering were made based on pilot feedback, enhancing comprehension and flow without altering the substantive content or measurement properties.

**Data Collection Procedures**

The survey was administered via Google Forms, a web-based platform enabling efficient distribution, real-time response monitoring, automatic data validation, and direct export to statistical software (Evans & Mathur, 2018; Wright, 2005). Online administration offered advantages of geographic reach, reduced data entry errors, lower costs, and faster completion relative to paper-based alternatives, while acknowledging limitations regarding digital access and potential self-selection bias (Fan & Yan, 2010).

Respondent recruitment employed multiple channels to maximize sample diversity. Invitations were distributed through: (1) social media platforms, particularly Facebook groups focused on entrepreneurship, biotechnology, marine science, and sustainability; (2) professional networks including LinkedIn connections of researchers and practitioners in relevant sectors; (3) university student and faculty listservs at institutions with marine science, biotechnology, environmental science, and business programs; (4) direct email to individuals affiliated with government agencies managing marine resources, environmental NGOs, aquaculture associations, and startup support organizations; and (5) snowball referrals wherein initial respondents forwarded the survey link to colleagues and peers meeting inclusion criteria.

The survey landing page provided comprehensive information including research purpose, principal investigator affiliation, confidentiality assurances, voluntary participation notice, estimated completion time (10–12 minutes), and researcher contact details for questions or concerns. All survey items were configured as required fields in Google Forms to minimize missing data; however, respondents could exit at any point without submitting their responses. To enhance response rates, two reminder messages were sent via the same distribution channels at one-week and two-week intervals following initial invitations (Dillman *et al.,* 2014). No monetary or material incentives were offered for participation.

**Data Management and Quality Control**

Completed responses were automatically captured in Google Forms and exported to Microsoft Excel for preliminary cleaning before transfer to SPSS version 27.0 for statistical analysis (IBM Corp., 2020). Data cleaning procedures included: (1) removing duplicate submissions based on timestamp and response pattern examination; (2) verifying that all responses fell within valid ranges for each variable; (3) checking for logical inconsistencies (e.g., doctoral degree holders aged 18–24); (4) examining completion times to identify potentially careless responding (submissions completed in <3 minutes flagged for review); and (5) inspecting straight-lining patterns wherein respondents selected the same response category across multiple items.

All 223 submitted responses met quality criteria and were retained for analysis. No duplicates were detected; all responses exhibited plausible demographic combinations. Completion times ranged from 4 to 27 minutes (median = 11 minutes), and response patterns demonstrated variation consistent with engaged participation. Missing data were minimal (0% on demographic and core variables; <1% on two optional items) due to required field configuration in Google Forms.

**Statistical Analysis Procedures**

**Descriptive Statistics**

Frequency distributions and percentages were calculated for all categorical variables to characterize sample composition and response patterns (Field, 2024). For ordinal variables, measures of central tendency (mean, median, mode) and dispersion (standard deviation, range, variance) were computed to summarize distributions. Bar charts were generated to visualize frequency distributions for key variables, including demographic characteristics, blue biotechnology familiarity levels, perceived opportunities, challenges, and entrepreneurial intentions.

**Bivariate Analysis**

Cross-tabulation with chi-square tests of independence examined associations between categorical variables (Agresti, 2007). Specifically, demographic variables (gender, age, education, and occupation) were cross-tabulated with outcome variables, including blue economy awareness, familiarity with blue biotechnology, entrepreneurial intentions, perceptions of opportunities, assessments of challenges, and likelihood of investment. Chi-square tests evaluated whether response distributions differed significantly across demographic categories, with null hypotheses of independence tested at a significance level of $\alpha = .05$ (McHugh, 2013).

For 2×2 contingency tables, Fisher's exact test replaced the chi-square test when the expected cell frequencies fell below 5 to maintain test validity under sparse data conditions (Agresti, 2007). For larger tables where >20% of cells exhibited expected frequencies <5, likelihood ratio statistics were reported as more robust alternatives to Pearson chi-square (Field, 2024). Post-hoc pairwise comparisons of column proportions employed z-tests with Bonferroni-adjusted alpha levels to control Type I error inflation from multiple comparisons (Agresti, 2007). In SPSS crosstabulation output, shared subscript letters indicate column proportions not differing significantly at the adjusted significance level.

Pearson's product-moment correlation (r) assessed linear relationships between ordinal and interval-level variables (Cohen, 1988), with coefficients interpreted using conventional benchmarks: $|r| = 0.10–0.29$ as weak, 0.30–0.49 as moderate, and ≥0.50 as strong associations. For strictly ordinal variables, Spearman's rank correlation ($\rho$) served as a non-parametric alternative robust to non-normality and non-linearity (Myers & Sirois, 2006). All tests were two-tailed with exact p-values reported alongside test statistics and degrees of freedom.

### Ethical Considerations

The research adhered to ethical principles for human subjects research articulated in the Declaration of Helsinki and institutional research ethics guidelines (World Medical Association, 2013). Specific safeguards included:

### Informed Consent

The survey introduction page provided comprehensive information regarding the research purpose, procedures, voluntary participation, right to withdraw without penalty, data confidentiality protections, and the researcher's contact information. Proceeding beyond the introduction page constituted implied consent, in accordance with the standards for minimal-risk survey research (Dillman *et al.,* 2014).

### Anonymity and Confidentiality

No personally identifiable information (such as names, email addresses, phone numbers, or IP addresses) was collected. Responses were stored with randomly assigned numeric identifiers only. Data files are stored on password-protected devices, accessible exclusively to the research team. Only aggregate results are reported, precluding individual identification.

### Voluntary Participation

Respondents could discontinue participation at any point without providing justification. No coercion or undue inducements were employed. The voluntary nature of participation was explicitly stated in recruitment materials and the survey introduction.

### Data Security

Electronic data are maintained on encrypted drives with secure backup protocols. Data will be retained for five years following publication to permit verification and replication, after which permanent deletion will occur in accordance with institutional data retention policies.

### Methodological Limitations

Several limitations warrant acknowledgment. First, non-probability sampling limits the generalizability to the broader Bangladesh population, as respondents were not randomly selected and may differ systematically from non-respondents in ways that affect survey responses (Etikan *et al.,* 2016). Individuals with prior interest in blue economy or biotechnology topics likely exhibited higher participation propensity, potentially introducing selection bias toward more knowledgeable and favorably disposed respondents. Second, the cross-sectional design captures attitudes at a single time point, precluding examination of awareness evolution, intention stability, or temporal changes in opportunity/challenge perceptions as Bangladesh's blue biotechnology sector develops. Third, self-report measures are susceptible to social desirability bias, whereby respondents may provide answers that are perceived as more favorable rather than accurate reflections of their true beliefs or intentions (Podsakoff *et al.,* 2003). The high entrepreneurial intention rate (93.3%) may partially reflect aspirational rather than actionable commitments. Fourth, English language administration potentially excluded individuals with limited English proficiency despite relevant expertise, though Bangladesh's higher education system employs English as primary medium, mitigating this concern for the educationally qualified sample. Fifth, online administration restricted participation to individuals with internet access and digital literacy, potentially underrepresenting older demographics, rural populations, and lower socioeconomic segments (Wright, 2005). Finally, the absence of pre-existing validated scales for blue biotechnology entrepreneurship necessitated original item development, which, despite pilot testing, may exhibit measurement properties inferior to psychometrically established instruments.

## RESULTS AND DISCUSSION

The findings section presents quantitative results from a survey of 223 respondents regarding their awareness of blue biotechnology, opportunities, challenges, and entrepreneurial intentions in Bangladesh. Results are organized thematically with emphasis on statistically significant relationships identified through chi-square tests and correlation analyses.

### Sample Characteristics and Blue Biotechnology Knowledge Baseline

The sample (N = 223) consisted predominantly of males (71.3%, n = 159) and younger respondents, with 78.5% falling between the ages of 18 and 34. Educational attainment was high, with 87.4% holding bachelor's degrees or higher, including 35.0% with master's degrees and 6.7% with doctoral or postdoctoral credentials. Nearly half (48.0%) identified as students, with the remainder employed in the private sector (23.8%), government (20.6%), business (5.4%), or other occupations (2.2%).

Blue biotechnology familiarity proved to be limited, despite high general awareness of the blue economy. While 96.0% (n=214) reported knowing about the blue economy, only 40.8% (n=91) characterized themselves as "very familiar" and 33.6% (n=75) as "somewhat familiar" with blue biotechnology specifically. A substantial 59.2% indicated low or no familiarity (17.5% "not very familiar"; 8.1% "not at all familiar"), revealing a significant knowledge gap. Critically, only 26.9% (n=60) reported any work experience in blue biotechnology industry, underscoring the sector's nascent development stage in Bangladesh.

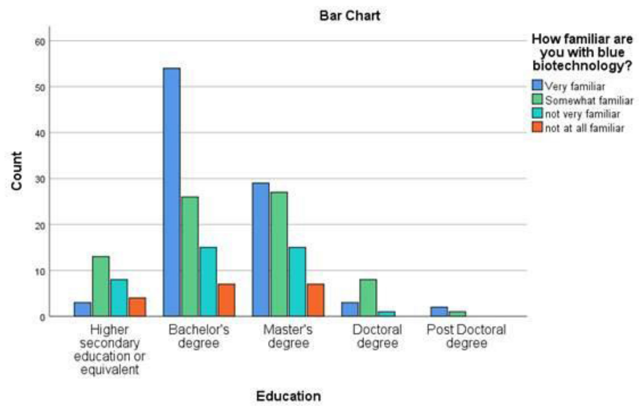


**Figure 1:** Blue Biotechnology Familiarity Levels by Occupation

Belief in the future viability of blue biotechnology in Bangladesh garnered overwhelming consensus, with 96.9% (n=216) affirmatively answering that "blue biotech has a future in Bangladesh," and no significant variation by gender ($\chi^2$=0.708, p=.400) or occupation. Similarly, 95.1% (n=212) agreed that seaweed, biofuels, and marine bioactive substances "bring value to the economy of Bangladesh," and 99.1% (n=221) believed blue biotechnology could "help Bangladesh retain its ecological balance and lush vegetation."

**Perceived Opportunities for Blue Biotechnology Startups**

Respondents identified four primary opportunity categories for blue biotechnology ventures in Bangladesh, with resource endowment and market demand emerging as dominant themes. Availability of raw materials (marine resources) represented the single most cited opportunity (43.5%, n=97), reflecting awareness of Bangladesh's expanded maritime territory. Growing demand for seafood products ranked second (30.5%, n=68), aligning with both domestic consumption trends and export potential. Increasing awareness of the benefits of blue biotechnology (25.6%, n=57) and favorable government policies (15.7%, n=35) received less emphasis.

Gender differences in opportunity perception proved statistically significant ($\chi^2$=15.756, df=3, p=.001). Males disproportionately emphasized growing seafood demand (43.4% vs. 43.8%), while females more frequently identified raw material availability (28.1% vs. 10.1%). This divergence may reflect different sectoral orientations or entrepreneurial focus areas between genders.

Regarding promising research domains, marine natural products commanded the greatest interest (39.9%, n=89), consistent with global pharmaceutical industry attention to marine-derived bioactive compounds. Aquaculture biotechnology ranked second (31.4%, n = 70), aligning with Bangladesh's established aquaculture sector. Marine genomics (15.7%, n=35) and bioremediation (13.0%, n=29) attracted more limited but non-trivial attention. No significant demographic variations emerged in research area preferences ($\chi^2$=5.507, df=3, p=.138).

**Entrepreneurial Intentions and Startup Business Planning**

Entrepreneurial enthusiasm for blue economy ventures proved remarkably robust: 93.3% (n=208) expressed desire to launch a blue economy startup, versus only 6.7% (n=15) declining interest. This high intention rate persisted across demographic segments without significant gender ($\chi^2$=1.856, p=.173), age, education, or occupational variation, suggesting a broad-based entrepreneurial spirit transcending traditional demographic predictors.

Among prospective entrepreneurs, target audience strategies are divided almost evenly between focused and broad approaches. Approximately 70.0% (n = 156) indicated an intention to serve "specific target audiences" through market segmentation, while 30.0% (n = 67) selected "everyone" as their target, implying mass-market

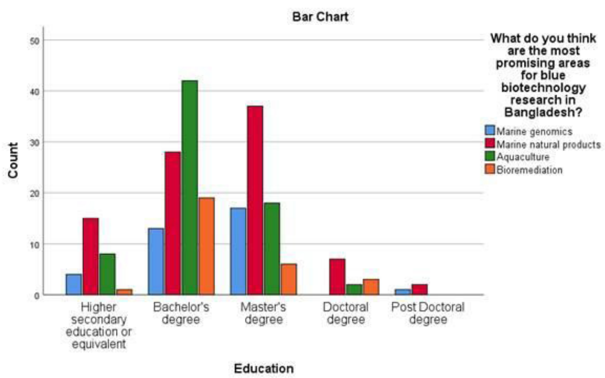


**Figure 2:** Most Promising Blue Biotechnology Research Areas by Education

strategies. Gender differences emerged as marginally significant ($\chi^2$=4.045, p=.044), with males slightly more likely to pursue niche targeting than females.

Sector preferences revealed concentration in specific blue economy domains. Shipping and transportation attracted 30.9% (n=69), fisheries and aquaculture 26.0% (n=58), marine resource extraction 10.8% (n=24), ocean-dependent tourism 20.2% (n=45), and conservation of biodiversity 12.1% (n=27). Notably, shipping's prominence contrasts with blue biotechnology's typical association with fisheries, aquaculture, and natural products, suggesting either a broader blue economy conceptualization or conflation of sectors among respondents. Chi-square analysis confirmed significant gender differences ($\chi^2$=14.600, df=4, p=.006), with males favoring shipping (34.6% vs. 21.9%) and females showing relatively greater interest in conservation and fisheries.

Marketing strategy preferences strongly favored digital channels: 64.6% (n = 144) selected "best online marketing strategy" versus 35.4% (n = 79) who preferred offline approaches. This digital orientation aligns with Bangladesh's high social media penetration and respondents' younger demographic profile. A gender comparison revealed significant differences ($\chi^2$ = 4.265, p = .039), with males being more inclined toward online strategies (60.4%) than females (75.0%).

Competitive landscape assessments indicated that 70.0% (n=156) expected primary competition from "outside Bangladesh" (presumably international firms), while 30.0% (n=67) anticipated domestic competitors. This suggests recognition that blue biotechnology ventures would compete in global markets from inception, facing established multinational corporations rather than solely local rivals.

### Perceived Challenges Facing Blue Biotechnology Startups

Challenge identification revealed consensus around capital and infrastructure constraints as paramount barriers. Lack of funding was overwhelmingly cited (30.0%, n=67) by nearly one-third of respondents as the single greatest challenge. Lack of skilled workforce ranked second (30.9%, n=69), followed by lack of infrastructure (18.4%, n=41) and lack of government support (20.6%, n=46). This distribution highlights the perception that the primary constraints of blue biotechnology are resource-based (financial, human, and physical) rather than regulatory or market-related.

Statistical analysis revealed significant variation in challenge perception across age groups ($\chi^2$ = 35.917, df = 12, p < .001). Younger respondents (18–24)

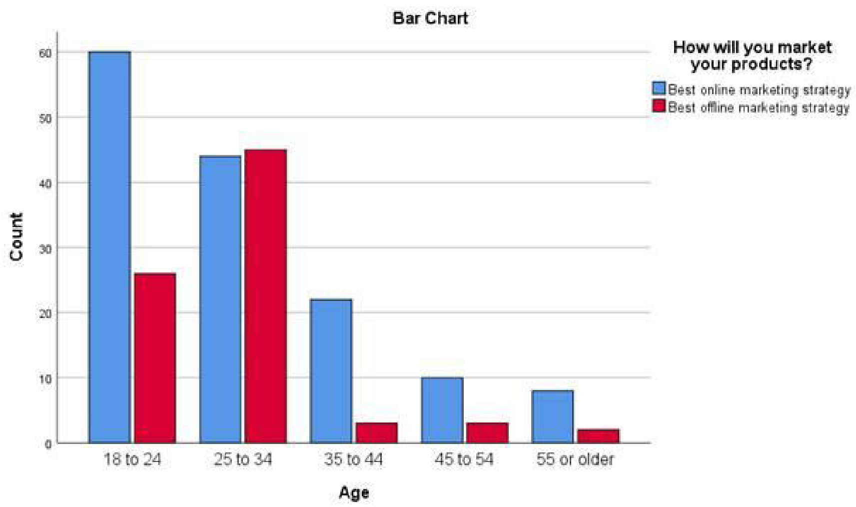


**Figure 3:** Preferred Marketing Strategies for Blue Economy Startups by Age

more frequently identified government support deficits (29.1%) relative to other age cohorts, while middle-aged respondents (35–44) disproportionately emphasized infrastructure limitations (44.0%) and skilled workforce shortages (44.0%). This age-related variation likely reflects differential exposure to entrepreneurial realities, with older respondents possessing greater direct experience with infrastructure and talent constraints.

When asked specifically which challenges blue biotech startups would "expect to face the most" during operations, the investment crisis because of a new area dominated (75.3%, n=168), far exceeding maritime law complexities (20.2%, n=45) or admiralty law issues (4.5%, n=10). This finding reinforces that financial access represents the overwhelming operational concern, surpassing legal or regulatory dimensions. No significant demographic patterns emerged in this assessment.

### Investment Intentions and Decision Factors

Investment propensity toward blue biotechnology startups proved more cautious than entrepreneurial intentions, revealing a notable gap between intention and investment. While 93.3% expressed interest in starting a startup, only 53.4% (n=119) indicated they were "very likely" to invest, with 32.3% (n=72) "somewhat likely," 8.1% (n=18) "not very likely," and 6.3% (n=14) "not at all likely." This suggests that while entrepreneurship appeals broadly, committing personal capital generates greater hesitation, possibly reflecting risk aversion or capital constraints.

Age emerged as a significant moderator of investment likelihood ($\chi^2$ = 22.515, df = 12, p = .032). Younger respondents (18–24 and 25–34) demonstrated higher investment propensity (47.7% and 64.0% "very likely," respectively) compared to middle-aged groups (35–44: 28.0% "very likely"). However, these differences must be interpreted cautiously, given that younger respondents may possess less capital to invest, rendering stated intentions potentially aspirational rather than actionable.

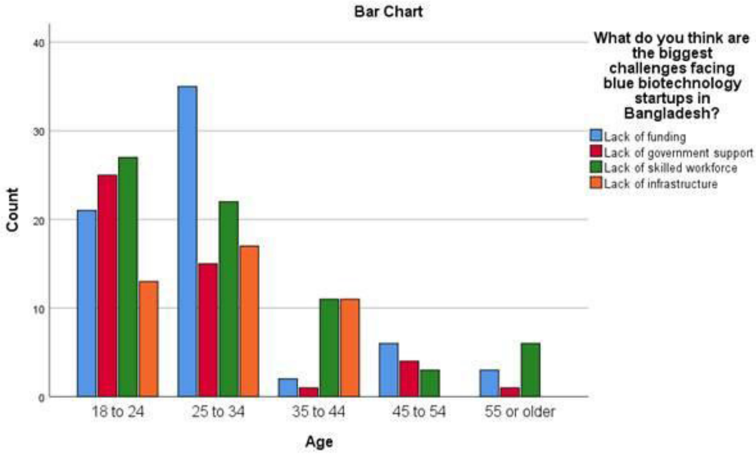


**Figure 4:** Biggest Challenges Facing Blue Biotechnology Startups by Age Group

Factors influencing investment decisions are distributed as follows: the potential market size (37.2%, n=83), the quality of the management team (34.5%, n=77), the level of innovation (23.8%, n=53), and multiple factors simultaneously (4.5%, n=10). Market size's primacy indicates conventional investor logic emphasizing commercial viability over technological novelty per se. No significant gender differences emerged ($\chi^2$=3.264, p=.353), suggesting consensus on investment criteria across demographic segments.

**Ecosystem Support Requirements**

University-industry collaboration emerged as a critical perceived success factor. When asked how important it is for blue biotechnology startups to collaborate with universities and research institutions, 85.2% (n=190) responded "very important" and 14.8% (n=33) "somewhat important," yielding near-universal (100%) recognition of academia's essential role. No respondents selected lower importance levels, and no significant demographic variation emerged ($\chi^2$=2.094, p=.148), indicating cross-cutting consensus.

This finding aligns with theoretical frameworks emphasizing knowledge transfer from public research to commercial ventures, particularly in science-intensive sectors like biotechnology, where universities generate foundational discoveries that startups subsequently develop and commercialize.

**Comprehensive Blue Biotechnology Landscape Summary**

Table 1 consolidates key findings across all measured dimensions, providing integrated perspective on Bangladesh's blue biotechnology startup opportunity structure and constraint set.

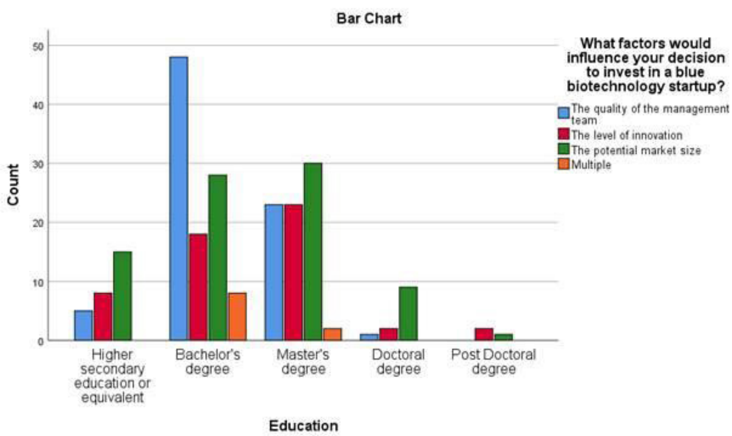


**Figure 5:** Factors Influencing Investment Decisions in Blue Biotechnology Startups by Education Levels

**Key Findings Summary**

Five overarching patterns emerge from the empirical data. First, a pronounced awareness-knowledge gap exists: while blue economy awareness reaches 96%, blue biotechnology familiarity remains below 41%, signaling need for targeted education and capacity building. Second, resource endowment and market demand dominate opportunity perceptions, with marine raw material availability and seafood demand surpassing policy or awareness factors. Third, capital constraints emerge as the overwhelming challenge, cited by 30–75% of respondents, depending on the question framing, far exceeding concerns related to regulation, technical issues, or market access. Fourth, a significant intention-investment gap exists between entrepreneurial enthusiasm (93%) and investment willingness (53%), suggesting that risk perceptions or capital limitations temper financial commitments despite startup interest. Fifth, ecosystem integration through university-industry collaboration garners universal recognition (100%), indicating a consensus that blue biotechnology's knowledge intensity necessitates strong academic-industry linkages.

**Table 1:** Integrated Summary of Blue Biotechnology Awareness, Opportunities, Challenges, and Intentions in Bangladesh (N=223)

| Dimension | Measure | Result | Statistical Significance |
|---|---|---|---|
| Knowledge & Awareness | Blue economy awareness | 96.0% aware | Gender difference: $\chi^2$=23.300, p<.001* |
| | Blue biotechnology familiarity (very/somewhat) | 40.8% familiar | No gender difference: $\chi^2$=4.098, p=.251 |
| | Industry work experience | 26.9% yes | No gender difference: $\chi^2$=0.353, p=.552 |
| | Belief blue biotech has future in Bangladesh | 96.9% yes | No differences across demographics |
| Opportunities | Top opportunity: Availability of raw materials | 43.5% | Gender difference: $\chi^2$=15.756, p=.001* |
| | Second: Growing seafood demand | 30.5% | — |
| | Most promising research: Marine natural products | 39.9% | No demographic differences |
| | Second: Aquaculture biotechnology | 31.4% | — |
| Entrepreneurial Intentions | Want to start blue economy startup | 93.3% yes | No gender difference: $\chi^2$=1.856, p=.173 |
| | Preferred sector: Shipping/ transportation | 30.9% | Gender difference: $\chi^2$=14.600, p=.006* |
| | Target audience: Specific vs. everyone | 70.0% specific | Marginal gender effect: $\chi^2$=4.045, p=.044* |
| | Marketing preference: Online | 64.6% | Gender difference: $\chi^2$=4.265, p=.039* |
| | Expected competitors: Outside Bangladesh | 70.0% | No gender difference |
| Challenges | Biggest challenge: Lack of funding | 30.0% | Age difference: $\chi^2$=35.917, p<.001* |
| | Second: Lack of skilled workforce | 30.9% | — |
| | Operational challenge: Investment crisis | 75.3% | No demographic patterns |
| Investment | Very likely to invest | 53.4% | Age difference: $\chi^2$=22.515, p=.032* |
| | Top investment factor: Market size | 37.2% | No gender difference: $\chi^2$=3.264, p=.353 |
| | Second: Management team quality | 34.5% | — |
| Ecosystem | University collaboration very/ somewhat important | 100% | No differences: $\chi^2$=2.094, p=.148 |
| Perceptions | Blue biotech brings value to economy | 95.1% agree | No demographic differences |
| | Can help ecological balance | 99.1% yes | — |

*Note. Asterisk (*) indicates statistical significance at p<.05 level. Chi-square values, degrees of freedom, and p-values reported for key relationships. Percentages calculated from valid responses (N=223); missing data <1% across all variables*

## CONCLUSION

Bangladesh stands at a critical juncture in blue biotechnology development, leveraging its rich marine biodiversity, expanded exclusive economic zone, and established aquaculture sector, yet facing severe institutional, financial, and infrastructural barriers that hinder progress. This first systematic study of 223 stakeholders reveals stark paradoxes: 93.3% entrepreneurial enthusiasm for startups, 96.9% confidence in sector viability, yet only 40.8% familiarity with blue biotechnology; 53.4%

investment intent amid capital scarcity cited as the top challenge (30-75%). Five key patterns emerge: awareness-knowledge gaps demanding targeted education; resource strengths in biodiversity and seafood risking narrow focus; capital barriers eclipsing regulatory or technical issues; intention-investment disconnects from risk and funding limits; and 100% endorsement of university-industry collaboration for knowledge transfer. Policy solutions include capacity-building programs, innovative financing like government venture funds and public-private partnerships, infrastructure investments in marine stations and biobanks, formalized academia-commercial links, and focus on marine natural products (39.9% interest) and aquaculture biotech (31.4%). Entrepreneurs should pursue hybrid models blending licensing with domestic development, strategic partnerships, balanced teams with scientific-business expertise, and international mentorship. Success hinges on coordinated policy in knowledge, capital, infrastructure, and linkages plus pragmatic entrepreneurship, transforming marine wealth into sustainable economic gains and blue economy contributions.

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