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Research Article

Lean Management and Regenerative Blue Economy: The Mediating Role of Employee Creativity

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Abstract: This study explores the mediating role of employee creativity in the relationship between Lean Management and regenerative sustainability in the blue economy. Using data from 220 aquaculture workers and Partial Least Squares Structural Equation Modelling, the results indicate that Lean Management positively influences regenerative sustainability (β = 0.350, p = 0.013), with employee creativity significantly mediating this effect (β = 0.247, p < 0.001). The findings highlight creativity as a key driver in translating Lean efficiency into regenerative innovation. The study recommends fostering an innovation-centric culture and integrating Lean practices with circular economy principles to advance marine ecosystem restoration. This research offers a practical framework for companies seeking to balance economic performance with environmental stewardship.

Keywords: Lean Management; Regenerative Sustainability; Blue Economy; Employee Creativity; Innovation; Sustainable Performance.

1. Introduction

The blue economy refers to economic activities that depend on marine and freshwater resources while seeking to preserve ecosystem health and generate social and economic value. In aquaculture, this perspective is particularly relevant because firms are increasingly expected to improve production efficiency, reduce environmental pressures, and contribute to the resilience of aquatic ecosystems.

Aquaculture enterprises operate in complex and uncertain conditions. Biological variability, disease risks, water-quality fluctuations, seasonal constraints, and stricter environmental regulations require firms to adopt more adaptive and responsible management practices. As a result, improving aquaculture performance can no longer be limited to economic outcomes. It must also integrate environmental restoration, social value creation, and long-term ecosystem resilience.

Lean Management offers a useful operational approach to address these challenges because it focuses on waste reduction, process improvement, employee involvement, and continuous improvement. However, the transition from operational efficiency to regenerative sustainability requires more than standardized routines.

It also depends on employees' ability to generate novel and useful ideas for solving operational and environmental problems. Employee creativity may therefore play a central role in translating Lean practices into regenerative outcomes.

Although previous studies have examined the relationship between Lean Management and sustainability, limited attention has been given to regenerative sustainability in the blue economy, particularly in the aquaculture sector.

Moreover, the mediating role of employee creativity in the relationship between Lean Management and regenerative sustainability remains underexplored. This gap is important because aquaculture requires both structured efficiency-oriented practices and creative problem-solving capabilities to address ecological and operational complexity.

Accordingly, this study examines the effect of Lean Management on regenerative sustainability in aquaculture enterprises and investigates the mediating role of employee creativity in this relationship.

Using data collected from 220 aquaculture workers and analysed through Partial Least Squares Structural Equation Modelling (PLS-SEM), this research contributes to the literature by integrating Lean Management, employee creativity, and regenerative sustainability within a blue economy framework. It also provides practical insights for aquaculture managers seeking to combine operational efficiency with ecosystem restoration and sustainable value creation.

2. Literature review

Lean Management is fundamentally centred on optimising processes, minimising waste, and enhancing value creation for customers. Its roots in the Toyota Production System established a rigorous approach to continuous improvement, resource efficiency, and respect for people.

2.1. Lean Management evolution and theoretical foundations

Modern sustainability requires organizations to address not just economic, but social and environmental goals reflecting the United Nations' Sustainable Development Goals such as affordable energy, ethical production, and circular economy strategies. Lean thinking naturally aligns with these goals by driving operational excellence: low-carbon technologies, smart systems, and sustainable supply chain practices are enabled through Lean's focus on process improvement and waste elimination.

Lean Management provides a robust framework for sustainable manufacturing (Aljinović et al., 2021). Its core practices include continuous improvement (Kaizen), value stream mapping, employee engagement, 5S methodology, and supplier collaboration, which systematically target waste and inefficiency. This translates to tangible environmental impact reductions in areas such as energy usage, material waste, and emissions. For example, Value Stream Mapping allows organisations to visualise and reduce both operational and environmental waste, while Kaizen fosters iterative progress in resource savings.

Sustainable Continuous Improvement integrates Lean tools with a broader commitment to leadership, governance, standardized practices, worker safety, and economic viability (Ghobadian et al., 2020). Leadership commitment and employee participation are essential for maintaining momentum and ensuring that Lean gains support overall business sustainability objectives. organisations adopting Lean can adapt rapidly to evolving consumer demands, increase flexibility and responsiveness, and maintain high levels of product quality all while minimising environmental impacts.

Lean's effectiveness hinges on the iterative development of workforce skills and adaptive capabilities, offering a direct connection to dynamic capabilities theory (Singh et al., 2025). As organisations restructure their processes around Lean, employee training and empowerment become critical, further driving productivity, innovation, and sustainability. In practical terms, Lean incorporates nine recognised practices: continuous improvement, just-in-time production, Kanban, supplier collaboration, total productive maintenance, the 5S system, batch/inventory reduction, cross-functional process development, and Kaizen circles.

Lean is now the most applicable production paradigm, providing organisations with the tools to realize flexibility, reduce costs, enhance quality, and boost customer satisfaction all core elements of contemporary sustainable business practice.

2.2. Employee creativity in organisational contexts

For more than 50 years, creativity has piqued the curiosity of scholars and professionals, especially in organisational psychology. Creativity is fundamental to the innovation process, fuelling the development of new equipment, processes, procedures, and products across both industry and social services (Amin & Roberts, 2008). (Amabile & Pratt, 2016) conceptualise employee creativity as the capacity to generate original concepts and ideas that facilitate organisational problem-solving.

Creativity acts as a strategic resource, offering competitive advantages to firms operating in dynamic business environments (Yoon et al., 2016). This aligns with the Resource-Based View, where creativity emerges as an intangible asset, allowing organisations to differentiate themselves in turbulent environments. Importantly, fostering. innovation through creativity is not only about individual capabilities, but also involves organisational culture, leadership practices, and environmental context.

Researchers consider creativity both as a product and a mental process, enabling measurement and differentiation of creativity types according to context (Amabile & Pratt, 2016). For organisational purposes, creativity is generally evaluated on the basis of originality, usefulness, and its potential to drive beneficial change (Anderson et al., 2014). Creativity unfolds across a continuum, including incremental adjustments as well as radical transformations.

Modern creativity theories emphasise multiple antecedents. (Amabile & Pratt, 2016) componential theory posits that creativity results from complex interactions between domain-relevant skills, creative thinking processes, and intrinsic motivation. Organisational climate, empowerment, and leadership style especially transformational leadership are positively linked to creative output via their influences on autonomy and engagement. Psychological empowerment and task autonomy increase intrinsic motivation, fostering. experimentation and risk-taking, while supportive leadership facilitates information sharing and knowledge exchange.

Effective workforce reskilling and continuous learning are critical enablers of Lean Management's success in driving regenerative sustainability. As organisations face rapid technological advancements and increasingly complex sustainability challenges, fostering. adaptive capabilities through targeted reskilling programmes becomes indispensable. (Chaker & Damak, 2024b) emphasise the strategic necessity of aligning workforce development initiatives with sustainability objectives to empower employees to respond innovatively to evolving operational demands. This alignment not only enhances employee creativity but also strengthens organisational resilience, ensuring that Lean systems remain dynamic and transformative in the face of environmental and economic uncertainties. Consequently, investing in reskilling and knowledge transfer is fundamental to sustaining the human capital required for the integration of Lean practices with regenerative sustainability goals.

Individual-level drivers such as grit and work engagement also predict enhanced creativity, with person-organisation fit and feedback acting as moderating and mediating mechanisms. Employees situated in environments supportive of information exchange and skill development are more likely to demonstrate risk-taking and adaptability, both essential for creative problem-solving (Shah et al., 2025). Organisational climates that promote changeability, risk tolerance, and encouragement of new ideas create fertile contexts for dynamic, adaptive, and innovative behaviours that drive continuous improvement.

Crucially, creativity is not an innate quality but can be cultivated through training, experience, and supportive work environments (Scott et al., 2004). The organisational conditions such as leadership style, autonomy, psychological safety, and culture of recognition play a critical role in enabling employees to realize their creative potential. This is particularly important for industries facing rapid technological and environmental change, where creativity functions as a dynamic capability enabling rapid adaptation and sustained competitiveness.

2.3. Regenerative sustainability: Theoretical foundations

Regenerative sustainability marks a pivotal evolution in sustainability paradigms by adopting an innovative and holistic perspective that transcends traditional and modern sustainability approaches (Gibbons, 2020). Rather than focusing solely on minimising harm and improving efficiency, regenerative sustainability envisions ecosystems and human societies as interconnected, self-organising living systems capable of adaptation, evolution, and co-creation (Yunibandhu & Hallinger, 2025).

This paradigm shift embraces the integration of internal and external dimensions of sustainability. Internal dimensions encompass values, beliefs, and paradigms—shaping worldviews and decision-making while external dimensions involve infrastructures, governance mechanisms, ecological systems, and institutional frameworks (Tàbara, 2023). Fostering. profound transformations in thinking and behaviours based on living systems principles such as adaptation and self- organisations, regenerative sustainability aims to create thriving, resilient socio-ecological systems.

Crucially, regenerative sustainability moves beyond maintaining the status quo, viewing the planet not as a static entity but as a dynamic network of interconnected systems capable of growth and healing. This worldview sees human development happening with the planet, emphasising mutualistic relationships rather than dominion over nature (Du Plessis, 2012). Instead of imposing rigid external controls, regenerative practices tap into the inherent capacities of biological and social systems to self-organise, adapt, and evolve, thereby enhancing the vitality, complexity, and resilience of all life forms.

An essential insight from recent scholarship highlights the foundational role of internal dimensions in achieving sustainability. Initiatives fail when they focus disproportionately on external systems without cultivating the internal qualities such as compassion, creativity, and reflexivity of individuals and communities. The reciprocal relationship between internal values and external structures calls for deliberate efforts to develop inner capacities through participatory governance, community rituals, education for sustainability, and policies that support diversity and local sovereignty (Gibbons, 2020) (Manuel-Navarrete et al., 2025).

Applied to marine and aquaculture contexts, regenerative sustainability integrates multiple synergistic approaches. These include:

- Regenerative Development (RD): A place-centred, participatory methodology that enhances living system complexity and resilience by nurturing mutualistic human-nature interactions and continuous adaptation. Tools like LENSES and Regenesis operationalize this framework locally, supporting biodiversity and ecosystem health (Gibbons et al., 2020).
- Regenerative Community Development (RCD): This approach treats communities as complex adaptive systems where social, ecological, and cultural processes align to drive system-wide regeneration at scales ranging from neighbourhoods to bioregions, exemplified by ecovillage models.
- Regenerative Design: Employs methodologies such as permaculture, biomimicry, and biophilic design to create infrastructure that restores ecosystems, builds resilience, and fosters environments thriving in harmony with nature (Benne & Mang, 2015).
- Regenerative Food Systems and Agriculture: Implements practices like holistic grazing, agroforestry, and composting to enhance biodiversity, soil health, and food sovereignty, securing long-term ecological and social benefits (Gosnell et al., 2019).
- Regenerative Capitalism: Redefines economic success as systemic wellbeing, emphasising inclusive, resilient, and localised economies that sustain collective prosperity by aligning economic systems with living systems principles (Gonzalez-Perez & Piedrahita-Carvajal, 2022).
- Regenerative Governance: Advocates for distributed authority models such as sociocracy and holacracy to improve transparency, adaptability, and coordination across multiple governance scales, fostering. more responsive and inclusive decision-making (Rau & Koch-Gonzalez, 2018).

Together, these regenerative practices provide a comprehensive framework that transforms the blue economy, particularly aquaculture, by promoting not only sustainability but active regeneration of ecological, social, and economic vitality. This is essential given the heightened vulnerabilities of marine ecosystems to climate change, pollution, and overexploitation. Embracing regenerative sustainability invites aquaculture to shift from extractive models toward ones that restore biodiversity, rebuild ecosystem services, and support resilient livelihoods in coastal and marine communities.

Frameworks rooted in living systems thinking foster a transition in aquaculture towards integrated multi-trophic systems, circular nutrient flows, and community-based management that ensure long-term productivity and ecosystem health. This aligns with emerging scientific consensus and policy directives prioritising ecosystem-based management, climate adaptation, and social equity (FAO, 2024; IDRC, 2024). Such approaches enable the blue economy to fulfil multiple sustainable development objectives simultaneously while fostering. innovation, stewardship, and inclusiveness at all scales.

2.4. Contextual Application to the Blue Economy and Aquaculture

The integration of Lean Management, employee creativity, and regenerative sustainability hinges on the concept of dynamic capabilities, defined as organisational abilities to sense, seize, and reconfigure resources in response to changing environments. Lean Management cultivates these dynamic capabilities by establishing structured routines such as continuous improvement and waste elimination, which empower employees to engage creatively in problem-solving and innovation.

A critical aspect of aligning Lean Management practices with sustainability objectives lies in the strategic integration of human resource management practices. As highlighted by (Chaker & Damak, 2024a), developing a strategic framework to align human resource management with sustainability goals strengthens organisations capacity to mobilise, develop, and retain the talent essential for sustainable innovation. This framework emphasises cultivating an organisational culture that values employee creativity while integrating ongoing training and knowledge transfer processes. These components are pivotal for Lean Management to fully realize its positive effects on regenerative sustainability by facilitating the creation of dynamic capabilities through proactive human resource engagement.

Within this framework, reinforcing feedback loops exist, wherein Lean practices stimulate creativity by fostering. environments that encourage experimentation and knowledge sharing. Enhanced creativity subsequently drives the development of new regenerative practices, bolstering both environmental and organisational resilience. These regenerative practices, in turn, reshape the Lean system by embedding sustainability as a core value, creating a virtuous cycle of continuous socio-ecological improvement.

When applied to the blue economy, particularly the aquaculture sector, this integrated framework must consider several contextual characteristics. Aquaculture faces seasonality constraints because of biological growth cycles and environmental conditions that challenge production flexibility. It also operates under stringent regulatory pressures aimed at protecting marine ecosystems and ensuring food safety, requiring concurrent compliance and innovation. Further, the biological complexity of species and ecosystems introduces variability and uncertainty, demanding adaptive management supported by dynamic capabilities.

These sector-specific factors underscore the necessity for aquaculture enterprises to develop agile, learning-oriented cultures where Lean facilitates real-time responsiveness and employee creativity drives novel solutions to sustainability challenges. For example, Lean tools tailored for aquaculture could integrate environmental monitoring data into continuous improvement cycles, directly linking operational efficiency with ecological health metrics.

Overall, this integrated theoretical framework illustrates how Lean Management functions as a foundational capability builder that not only enhances creativity but also advances regenerative sustainability. Such synergy enables aquaculture organisations to navigate complexity, comply with evolving regulations, optimise resource use, and contribute actively to the resilience of marine ecosystems and communities.

3. Theoretical Integration and Hypothesis Development

The integration of Lean Management, employee creativity, and regenerative sustainability within aquaculture enterprises is theoretically grounded in Dynamic Capabilities Theory (Kippenberger, 1997). Dynamic capabilities represent an organisation's ability to sense, seize, and reconfigure resources and competencies in response to rapidly changing environments. This theoretical foundation is particularly relevant for aquaculture, where firms must adapt to biological cycles, regulatory changes, and environmental pressures while maintaining operational efficiency and sustainability goals.

Lean Management serves as a foundational capability builder by establishing structured routines and continuous improvement processes that enhance organisational sensing and learning capabilities. Through practices such as Kaizen, waste elimination, and cross-functional collaboration, Lean creates an organisational infrastructure that systematically identifies inefficiencies and opportunities for innovation. This structured approach to problem-solving directly enables employee creativity by providing frameworks for experimentation and knowledge sharing within safe-to-fail environments.

The theoretical model proposes mutually reinforcing feedback loops between the three core constructs. Lean practices foster employee creativity by establishing psychological safety, empowerment, and structured problem-solving approaches that encourage innovative thinking. Enhanced creativity, in turn, generates novel solutions for regenerative sustainability challenges, such as developing circular nutrient flows or biomimetic system designs. These regenerative innovations then influence Lean systems by expanding the definition of "value" beyond operational efficiency to include ecological and social outcomes, creating a virtuous cycle of continuous socio-ecological improvement.

3.1. Contextual Application to Blue Economy and Aquaculture

The aquaculture sector presents unique contextual characteristics that influence the theoretical relationships between Lean, creativity, and regenerative sustainability. Biological complexity introduces inherent variability in growth cycles, disease susceptibility, and environmental sensitivity, requiring adaptive management approaches that leverage dynamic capabilities. Seasonality constraints impose temporal limitations on production flexibility, demanding creative solutions that optimise resource utilisation across varying conditions.

Regulatory pressures in aquaculture are intensifying globally, with requirements for environmental impact assessments, water quality monitoring, and sustainable feed sourcing. These regulatory frameworks create both constraints and opportunities for innovation, where creative employees can develop solutions that ensure compliance while enhancing operational efficiency through Lean practices.

The Blue Economy framework emphasises sustainable ocean-based economic activities that contribute to ecosystem restoration while generating economic value. In this context, regenerative aquaculture practices such as integrated multi-trophic aquaculture, ecosystem service restoration, and circular economy approaches align with both Lean efficiency principles and creative problem-solving imperatives.

3.2. Conceptual model development

This study adopts a quantitative, cross-sectional survey design to examine the relationships between Lean Management (LM), Regenerative Sustainability (RS), and the blue economy in the aquaculture sector. Employee Creativity (EC) is tested as a mediating variable linking LM to RS.

3.2.1. Lean Management (LM)

Lean Management is based on well-established practices designed to enhance organisational processes. These practices include: (1) continuous improvement; (2) just-in-time production; (3) the Kanban system; (4) supplier development and collaboration; (5) total productive maintenance; (6) the 5S methodology; (7) batch and inventory reduction; (8) cross-functional employee training and process development; and (9) Kaizen improvement circles (Naeemah & Wong, 2023).

3.2.2. Employee Creativity (EC)

Employee creativity is driven by several key factors that foster innovation in an organisational setting. These factors include: (1) assessment through reliable tools, such as (Baer & Oldham, 2006) four-item scale, which evaluates employees' ability to generate ideas and solve problems innovatively; (2) the role of leadership, particularly empowering leadership, which enhances creativity by encouraging idea-sharing and risk-taking (Neuenfeldt & Sulíková, 2024); (3) employees' adaptability, which enables them to respond effectively to rapid changes in the work environment (Barua et al., 2024); (4) employee empowerment, which facilitates the acceptance and integration of change, thereby strengthening creative potential (Barua et al., 2024); and (5) the promotion of risk-taking, a crucial element in supporting innovative initiatives and fostering a creativity-friendly environment (Gorzelany et al., 2021).

3.2.3. Regenerative Practices (RD)

Regenerative practices are evaluated using key indicators specific to each dimension. These include: (1) regenerative development, assessed through biodiversity and ecological resilience, drawing on the work of (Gibbons et al., 2020); (2) regenerative community development, which examines the availability and quality of local resources such as water, food, and energy; (3) regenerative design, incorporating principles of biomimicry and permaculture (Andreucci et al., 2021); (4) regenerative food systems, analysed through soil organic matter levels and water quality (Gosnell et al., 2019); (5) regenerative capitalism, studied using multi-capital indicators encompassing financial, natural, and social dimensions; and (6) regenerative governance, measured by the accessibility and frequency of internal reports (Rau & Koch-Gonzalez, 2018).

3.3. Hypothesis Development

Based on the theoretical integration and contextual analysis, two primary hypotheses are proposed.

3.3.1. Hypotheses H1: Direct effect of lean management on regenerative sustainability

Lean Management practices positively and significantly influence regenerative sustainability outcomes in aquaculture enterprises. This relationship is theoretically grounded in a critical distinction: while traditional sustainability approaches aim to minimise harm, regenerative sustainability seeks to actively restore ecosystems and reverse environmental degradation. Lean Management plays a unique catalytic role in this paradigm shift. By systematically eliminating waste in all its forms time, materials, energy, and unnecessary movements Lean not only optimises operational efficiency but also frees up organisational resources (both financial and human) that can be strategically reallocated to ecosystem restoration initiatives. For example, savings from production waste reduction can finance marine regeneration projects such as mangrove restoration or integrated multi-trophic aquaculture, while time freed through process Optimisation enables teams to develop regenerative innovations. Thus, Lean practices enhance organisational capabilities to transition from extractive to restorative models, creating the material and organisational conditions necessary for aquaculture enterprises to contribute actively to marine ecosystem resilience.

3.3.2. Hypotheses H2: Mediating Role of Employee Creativity

Employee creativity mediates the relationship between Lean Management and regenerative sustainability through two complementary mechanisms: (1) Lean practices enhance employee creativity by providing structured frameworks for innovation and problem-solving; and (2) enhanced creativity enables the development of novel regenerative solutions that bridge operational efficiency with ecological restoration goals.

The mediating role of creativity is particularly embodied through Kaizen, which represents a structured form of incremental creativity. Unlike radical innovations that involve major disruptions, Kaizen fosters continuous, iterative, and collective creativity where each modest improvement accumulates to generate profound transformations. This approach possesses three essential characteristics: first, it relies on rigorous methodologies (PDCA cycles, systematic problem-solving) that channel creative energy toward concrete results; second, it democratises innovation by recognising that all employees, regardless of their hierarchical level, possess valuable tacit knowledge to improve processes; third, it integrates the experimental dimension by encouraging small-scale trials and learning from failure within a safe framework.

In the context of regenerative sustainability, Kaizen enables aquaculture workers to continuously test and refine regenerative practices for instance, optimising polyculture ratios to maximise carbon sequestration, or adjusting water management protocols to promote marine biodiversity.

This structured incremental creativity thus transforms Lean's operational focus into tangible regenerative innovation, establishing an operational bridge between continuous improvement and ecosystem restoration.

4. Methodology

This study adopts a quantitative, cross-sectional design to examine the mediating role of employee creativity in the relationship between Lean Management practices and regenerative sustainability within aquaculture enterprises.

4.1. Research design and approach

The analysis employs Partial Least Squares Structural Equation Modelling. (PLS-SEM) using Smart PLS 3 software. PLS-SEM was chosen because it is particularly suited to predictive research frameworks involving latent constructs, small-to-medium sample sizes, and non-normal data distributions.

It allows simultaneous estimation of measurement and structural models and is widely recommended for early-stage theoretical development and exploratory research focusing on mediation effects (J Hair et al., 2017).

Moreover, it provides robust estimates for complex models that include moderation and mediation with multiple latent variables, as is the case in this research.

4.2. Sample and data collection

The study sample comprised 220 employees working in aquaculture companies located along North African and Mediterranean coastal regions. Participants were selected using a purposive sampling approach, targeting individuals directly involved in production, quality, and sustainability operations. Most respondents were mid-level employees, technicians, or supervisors trained in Lean principles, while a smaller proportion held managerial or R&D positions.

The demographic profile was as follows: 68% male, 32% female; average age 34 years; average professional experience 7.8 years. Approximately 72% had received formal Lean Management training or sustainability-related education. The sample adequately met statistical power thresholds for PLS-SEM, exceeding the minimum recommended size of 200 for models with medium effect sizes and three latent constructs (Jr. et al., 2017a).

4.3. Data Collection Procedures

Data were collected between January and March 2024 using a structured, self-administered questionnaire distributed electronically through email and professional social networks such as LinkedIn and industry WhatsApp groups. These platforms were chosen to ensure wide geographic reach without limiting participation to specific organisations. To mitigate response bias, several procedural measures were taken:

- Respondents were assured of anonymity and confidentiality.
- Items were randomised within sections to reduce pattern responses.
- A five-point Likert scale (1 = strongly disagree, 5 = strongly agree) was used consistently to ensure comparability.
- Participation was voluntary, and respondents could withdraw at any time without consequence.

A pilot test with 25 respondents verified the clarity and reliability of questionnaire items. Minor revisions were made to improve readability and cultural relevance before full deployment.

4.4. Measurement of Variables

All constructs were operationalized using established scales validated in prior literature:

- Lean Management (LM) was measured using nine indicators representing core Lean practices: continuous improvement, Just-in-Time, Kanban, supplier collaboration, Total Productive Maintenance, 5S, inventory reduction, cross-functional training, and Kaizen circles (Naeemah & Wong, 2023).
- Employee Creativity (EC) was assessed using a five-item measure based on (Baer & Oldham, 2006), evaluating the ability to generate novel and useful ideas in problem-solving contexts.
- Regenerative Sustainability (RS) was measured through six indicators encompassing social, ecological, and economic regeneration adapted from (Gibbons et al., 2020) and verified through ecological management literature.

All constructs were measured reflectively. Scale reliability was confirmed using Cronbach's alpha (>0.85) and composite reliability (>0.90). Convergent validity was assessed through Average Variance Extracted values above 0.60, while discriminant validity was verified using Fornell-Larcker criteria.

5. Results

5.1. Descriptive statistics

The PLS-SEM analysis was conducted to evaluate both the measurement model (outer model) and the structural relationships (inner model). The measurement model assessment aimed to confirm the reliability and validity of the constructs before testing the hypotheses.

Table 2: Internal reliability.

Outer Loadings			
Items	Values	Cronbach's Alpha	Rho-A
LM1	0.792	0.929	0.930
LM2	0.786		
LM3	0.813		
LM4	0.797		
LM5	0.789		
LM6	0.828		
LM7	0.829		
LM8	0.796		
LM9	0.762		
EC1	0.784	0.853	0.857
EC2	0.830		
EC3	0.802		
EC4	0.774		
EC5	0.776		
RS1	0.855	0.891	0.908
RS2	0.777		
RS3	0.799		
RS4	0.879		
RS5	0.787		
RS6	0.717		

Source: Compiled by the authors

5.1.1. Reliability and construct validity

Table3: Reliability and convergent validity results.

	Reliability and construct validity	
	Composite Reliability	Average Variance Extracted (AVE)
RS	0.916	0.647
EC	0.895	0.629
LM	0.941	0.639

Source: Compiled by the authors

5.1.2 Internal reliability

Composite reliability and Cronbach's alpha were used in this study to assess internal reliability. According to Hair Jr. et al. (2017a), both measures should exceed the threshold value of 0.70 to be considered reliable. As shown in Table 2, the calculated Cronbach's alpha values for the constructs were 0.929, 0.853, and 0.891, all exceeding the recommended 0.70 criterion. These results confirm a strong level of internal reliability for the measurement model.

The reliability and convergent validity of the measurement model were assessed using composite reliability and Average Variance Extracted (AVE). As shown in Table 3, the composite reliability values for all constructs exceeded the recommended threshold of 0.70, with values of 0.916 for regenerative sustainability (RS), 0.895 for employee creativity (EC), and 0.941 for Lean Management (LM). These findings indicate satisfactory internal consistency reliability.

Convergent validity was assessed using factor loadings and AVE values. According to Hair et al. (2017), convergent validity reflects the extent to which indicators of the same construct are strongly associated. In addition, Fornell and Larcker (1981) recommend that AVE values should exceed 0.50 to establish convergent validity. As presented in Table 3, all factor loadings ranged from 0.717 to 0.879, and all AVE values were above the recommended threshold of 0.50, with values of 0.647 for RS, 0.629 for EC, and 0.639 for LM. Therefore, the measurement model satisfies the requirements for convergent validity.

Discriminant validity was assessed using the Fornell-Larcker criterion. This criterion requires that the square root of the AVE for each construct be greater than its correlations with other constructs. As shown in Table 4, the diagonal values represent the square roots of the AVE, while the off-diagonal values represent the inter-construct correlations. The results indicate that each construct shares more variance with its own indicators than with the other constructs, confirming discriminant validity.

Table 4: Discriminant Validity Results Using the Fornell-Larcker Criterion.

	EC	RS	LM
EC			
RS	0.467		
LM	0.401	0.499	

Source: Compiled by the authors

As shown in Table 5, the square root of the AVE for RS is 0.804, which is greater than its correlations with EC (0.640) and LM (0.597).

Similarly, the square root of the AVE for EC is 0.793, which is greater than its correlation with LM (0.556). Finally, the square root of the AVE for LM is 0.799, which is greater than its correlations with RS and EC.

These results confirm that the discriminant validity of the reflective constructs is established.

Table 5: Discriminant Validity Results (HTMT Ratio).

	RS	EC	LM
RS	0.804		
EC	0.640	0.793	
LM	0.597	0.556	0.799

Source: *Compiled by the authors*

While the Fornell-Larcker criterion has traditionally been used to assess discriminant validity, recent methodological developments suggest it may lack sensitivity (Henseler et al., 2015).

Therefore, we also examined the Heterotrait-Monotrait ratio of correlations (HTMT). As shown in Table 3, all HTMT values were below the conservative threshold of 0.85 (or 0.90 depending on your data), confirming that the constructs are empirically distinct and establishing robust discriminant validity.

5.2. Hypothesis testing outcomes

After validating the measurement model, the hypothesized relationships in the structural model were examined.

The assessment was based on path coefficients (β), standard deviations, t-values, and p-values obtained through a bootstrapping procedure with 5,000 subsamples.

As shown in Table 6, both hypotheses were supported. Lean Management had a positive and significant direct effect on regenerative sustainability (β = 0.350, t = 2.500, p = 0.013), supporting H1. In addition, the indirect effect of Lean Management on regenerative sustainability through employee creativity was positive and significant (β = 0.247, t = 3.640, p < 0.001), supporting H2.

Table 6: Hypothesis testing results.

Hypotheses	Original Sample (O)	Standard deviation (STDEV)	t-value	p- values	
H1	0.350	0.140	2.500	0.013	Accepted
H2	0.247	0.068	3.640	0.000	Accepted

Source: *Compiled by the authors*

The results for H1 indicate that Lean Management has a statistically significant and positive effect on regenerative sustainability. The standardised path coefficient of 0.350 suggests a moderate positive relationship. The t-value of 2.500 exceeds the critical threshold of 1.96 at the 5% significance level, and the p-value of 0.013 is below 0.05. Therefore, H1 is supported. This finding suggests that the implementation of Lean Management practices contributes to improved regenerative sustainability outcomes in aquaculture enterprises.

The results for H2 confirm the mediating role of employee creativity in the relationship between Lean Management and regenerative sustainability. The indirect effect is positive and statistically significant, with a path coefficient of 0.247, a t-value of 3.640, and a p-value below 0.001. Therefore, H2 is supported. This result indicates that employee creativity represents an important mechanism through which Lean Management enhances regenerative sustainability.

5.2.1. <u>Mediation analysis results</u>

The mediation analysis was conducted to further examine the mechanism through which Lean Management influences regenerative sustainability. Following the recommendations of Hair et al. (2017), the direct and indirect effects were assessed using bootstrapping with 5,000 resamples.

The results show that Lean Management has a significant direct effect on regenerative sustainability ($\beta = 0.350$, $t = 2.500$, $p = 0.013$). In addition, the indirect effect of Lean Management on regenerative sustainability through employee creativity is also significant ($\beta = 0.247$, $t = 3.640$, $p < 0.001$). Since both the direct and indirect effects are positive and significant, the findings indicate complementary partial mediation.

According to the mediation typology proposed by Zhao et al. (2010), complementary partial mediation occurs when both the direct effect and the indirect effect are significant and point in the same direction. In this study, this means that Lean Management enhances regenerative sustainability both directly, by improving resource efficiency and process stability, and indirectly, by stimulating employee creativity.

These findings suggest that employee creativity operates as a dynamic capability that helps transform Lean Management practices into regenerative value creation. In aquaculture enterprises, Lean routines such as continuous improvement, problem-solving, and employee involvement may encourage creative ideas that support waste reduction, resource Optimisation, circular practices, and ecosystem-oriented innovation.

5.2.2. <u>Explained Variance (R^2)</u>

The coefficient of determination (R^2) was used to assess the explanatory power of the structural model. R^2 indicates the proportion of variance in an endogenous construct that is explained by its predictor variables. As shown in Table 7, the model explains 49.4% of the variance in regenerative sustainability (RS), with an R^2 value of 0.494 and an adjusted R^2 value of 0.489. This indicates a satisfactory level of explanatory power for RS.

For employee creativity (EC), the R^2 value is 0.309, with an adjusted R^2 value of 0.305. This means that Lean Management explains 30.9% of the variance in employee creativity. These results suggest that the model explains regenerative sustainability more strongly than employee creativity. However, the R^2 value for EC remains acceptable and indicates that Lean Management plays an important role in explaining employees' creative capabilities. Additional organisational or contextual variables could further improve the explanatory power of the model.

Table 7: Coefficient of determination (R^2).

R^2	Adjusted square	
RS	0.494	0.489
EC	0.309	0.305

Source: *Compiled by the authors*

5.2.3. *Size's effect of the ƒ effect of Cohen or ƒ2*

The effect size (f^2) was used to evaluate the impact of each exogenous latent variable on the endogenous latent variable. The f^2 value indicates the extent to which an exogenous construct contributes to the explanatory power of the model by assessing the change in the R^2 value when the construct is omitted. As shown in Table 8, the effect sizes were interpreted according to Cohen's (2013) guidelines, as cited by Hair Jr. et al. (2017b), where values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively. It should also be noted that an effect size below 0.02 indicates no meaningful effect.

Table 8: size of the ƒ effect of Cohen (f^2).

	RS	EC
EC	0.271	
LM	0.167	0.446

Source: *Compiled by the authors*

The effect size of employee creativity on regenerative sustainability is 0.271, indicating a medium effect. This result suggests that employee creativity contributes meaningfully to explaining regenerative sustainability.

The effect size of Lean Management on regenerative sustainability is 0.167, which also indicates a medium effect. This means that Lean Management has a moderate contribution to regenerative sustainability outcomes.

The effect size of Lean Management on employee creativity is 0.446, indicating a large effect. This result highlights the strong role of Lean Management in fostering employee creativity. Overall, these findings suggest that Lean Management directly contributes to regenerative sustainability and strongly supports employee creativity, which in turn contributes to regenerative sustainability.

5.2.4. *Coefficient of Stone-Geisser (Q^2)*

By comparing the manifest variables of an endogenous latent variable to those of all the latent variables in the structural model, the Stone-Geisser coefficient (Q2), sometimes referred to as the cross-validated redundancy index, evaluates predictive validity (Hair et al., 2017b). A positive Q^2, as determined by the blindfolding process, denotes predictive validity, whereas a negative Q^2 implies a lack of validity, making the model inadequate (Roky & Meriouh, 2015). All Q2 values are positive, as the table illustrates, demonstrating the predictive validity of the model.

Table 9: coefficient of Stone-Geisser (Q^2).

	Q2
RS	0.292
EC	0.170

Source: *Compiled by the authors*

As shown in Table 9, all Q^2 values are positive. The Q^2 value for regenerative sustainability is 0.292, indicating that the model has adequate predictive relevance for RS. Similarly, the Q^2 value for employee creativity is 0.170, confirming predictive relevance for EC.

These results support the model's ability to predict the endogenous constructs.

5.2.5. *Total quality of the model: index of Goodness of Fit (GoF)*

The PLS-SEM approach does not provide a single comprehensive indicator for overall model validation. To address this limitation, Tenenhaus et al. (2005) developed the Goodness-of-Fit (GoF) index as a practical solution. The GoF index takes into account both the measurement model and the structural model simultaneously. As shown in Table 10, the GoF value was calculated to assess the overall fit and predictive quality of the proposed model.

It appears that the calculation formula consists of the geometrical means of the average of the communities (Average Variance Extracted (AVE)) and the average of the coefficients of determination (calculated for each endogenous variable).

Table 10: index of Goodness of Fit (GOF).

Calculation	Values
Average of the AVES	(0.647 + 0.629 + 0.639) / 3 = 0.638
Average of the R^2	(0.494 + 0.309) / 2 = 0.4015
GoF	0.506

Source: *Compiled by the authors*

Thus, the index of Goodness of Fit (GoF) of the model is 0.506. For (Wetzels et al., 2009), GoF higher than 0.36 indicates a good quality of the model. With a value of 0.506, the model thus has a good quality of adjustment. That means that the model structural and measurement combined have an excellent adequacy with the collected data. This high result of GoF consolidates the positive conclusions drawn from the detailed evaluation of the measurement model (reliability and validity) and the structural model (the assumptions' validation). Overall, the model demonstrates satisfactory explanatory and predictive quality.

5. Discussion

The impact of Lean Management on regenerative sustainability is a distinct concept that can interact to improve organisational performance. Lean management focuses on eliminating waste and optimising processes. In contrast, regenerative sustainability aims to restore natural resources and establish sustainable economic practices. Our findings show that lean management has a significant positive impact on regenerative sustainability (coefficient = 0.350, p = 0.013). This result aligns with research showing that lean practices enhance sustainability by reducing waste and optimising processes (Buer et al., 2021). For example, lean methods can improve an organisation's resilience to ecological and economic challenges while reducing its environmental impact (Garza-Reyes et al., 2018).

This positive relationship is supported by recent studies. Internal lean practices improve sustainable performance by strengthening social and environmental outcomes through better resource management (Chavez et al., 2022). Lean practices also positively influence all three dimensions of sustainable performance, regardless of firm size or the duration of lean adoption (Lizarelli et al., 2024). While both social and technical lean practices have similar effects on environmental and economic outcomes, social lean practices have a stronger positive impact on social performance (Lizarelli et al., 2024).

Furthermore, leadership aligned with lean management fosters sustainability by integrating green principles and promoting operational efficiency (Fayyaz et al., 2025). This approach aligns with circular economy principles by promoting regenerative processes for sustainable resource use (Kalemkerian et al., 2022). By adopting these methods, companies minimise waste and improve their environmental performance (Ouragini et al., 2024). Additionally, "soft" lean practices encourage green innovation, reinforcing their role in sustainability (AL-Bazaiah, 2023). The lean mindset also promotes eco-design from the start of the design process, which helps integrate environmental and economic performance (Andreazza De Freitas et al., 2025) and improves circularity (Ciliberto et al., 2021). Both lean and the circular economy are built on value creation and waste reduction. The circular economy's focus on end-of-life product disposal mirrors lean's emphasis on waste elimination (Rane & Nalaskar, 2021).

The Mediating Role of Employee Creativity

Employee creativity is an essential mediator in the relationship between lean management and regenerative sustainability. Our results show it plays a significant role (coefficient = 0.247, p = 0.000). This confirms that lean environments foster collaborative problem-solving and organisational innovation (Katz-Navon et al., 2024). Training in Lean Six Sigma and innovation also strengthens employees' creative identity and behaviours (Tan et al., 2024), validating our hypothesis that creativity amplifies the impact of lean practices.

Lean management is a strategic lever for achieving regenerative sustainability, with employee creativity as a key success factor. An environment conducive to innovation motivates employees to find creative solutions for operational and environmental challenges. This aligns with research that emphasises promoting an innovation culture (Tan et al., 2024), fostering employee autonomy (Tortorella et al., 2019), and implementing monitoring indicators.

By incorporating these elements, companies can make lean management a catalyst for continuous improvement. Employee empowerment and interdisciplinary collaboration foster innovative approaches that integrate sustainability into all aspects of the organisations. This integrated strategy improves competitiveness and resilience to environmental concerns (Afum et al., 2022).

The mediating effect of creativity is consistent with studies highlighting the importance of human factors (Hasanain, 2024). Employee engagement and creative behaviour are essential for turning operational efficiency into sustainable innovation. Lean practices foster creativity through ideation platforms and participative mechanisms (Tortorella et al., 2019).

Finally, employee creativity links human resources like knowledge and motivation to sustainable innovation performance (Muñoz-Pascual et al., 2021).

6. Managerial Implications and Recommendations

7.1. *Transforming Lean Practices into Regenerative Co-Creation Spaces*

Aquaculture managers should reframe Lean practices such as daily meetings, Kaizen circles, and structured problem-solving not merely as cost-reduction tools, but as strategic platforms for regenerative co-creation. Beyond monitoring operational KPIs, these practices should integrate ecosystem health indicators (e.g., water quality, biodiversity, waste valorisation), positioning employees as active contributors to both efficiency and environmental restoration.

Kaizen initiatives can be redirected toward regenerative innovation, including circular nutrient flows, biodegradable production materials, and eco-filtration systems. Likewise, problem-solving frameworks (A3, 5-Why, PDCA) should incorporate regenerative criteria alongside efficiency metrics, encouraging solutions that simultaneously improve performance and restore marine ecosystems. Allocating dedicated time for small-scale experimentation further supports incremental creativity and collaborative innovation.

7.2. *Building Regenerative Economic Loops*

By leveraging resources freed through waste reduction, aquaculture firms can invest in ecosystem restoration and strengthen local blue economies through partnerships with public and community stakeholders. Progress should be assessed using hybrid metrics combining operational performance with ecological indicators.

This study is limited by its cross-sectional design, regional sample (North African and Mediterranean aquaculture), and reliance on self-reported measures, which may affect causal inference and generalisability. Moreover, employee creativity was examined as the sole mediator, potentially overlooking other organisational capabilities and contextual factors. Despite these limitations, the findings provide initial empirical evidence supporting the mediating role of creativity in linking Lean Management to regenerative sustainability.

7. Conclusion

Although the literature has not yet fully explored the integration of Lean Management and regenerative sustainability within the blue economy, this study highlights their positive relationship, catalysed by employee creativity. This synergy represents a promising avenue for research and practice in aquaculture companies. By combining these approaches, organisations can enhance their operational efficiency while making significant contributions to a sustainable and regenerative blue economy.

Lean Management, renowned for its effectiveness in process Optimisation, is emerging as a critical tool for aquaculture companies aiming for sustainable practices. Its impact is amplified when employee creativity is harnessed to innovate and develop regenerative systems. Our findings show that Lean has a significant positive effect on regenerative sustainability, improving not only economic and environmental performance but also organisational resilience. Employee creativity acts as a key mediator, enabling the design of tailored solutions for sector-specific challenges.

This study contributes to the literature by proposing an integrated framework where Lean and regenerative sustainability, supported by creativity, converge to enhance performance. Aquaculture firms can optimise efficiency, strengthen competitiveness, and actively participate in revitalizing marine ecosystems. For instance, Lean practices can streamline feed usage and waste management, while creative solutions can lead to innovations like restorative shellfish and seaweed farming.

The implications of this research offer promising prospects. They underscore the importance of fostering an innovative environment, developing measurement tools for long-term sustainable impacts, and embedding regenerative practices into strategies. Adopting technologies like closed-loop aquaculture systems can align economic goals with environmental restoration. This model paves the way for a future where aquaculture companies harmonize economic performance with socio-environmental objectives, thereby contributing to the health of the oceans.

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