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Exploring Leader Member Exchange in the Environment of Shared Leaderships of Startups Under Incubation

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Abstract

The foundation of a productive work environment is effective leadership. It is predicated on cooperative alliances. Proficient leaders leverage the valuable input provided by their dedicated supporters, who complement their proficiencies with unique insights, new ideas, and persistent support. Studying how leaders and subordinates communicate with one another can help organizations to flourish. The success of shared leadership is investigated in this research. Incubation of firms entails a group of companions who collaborate due to similar passion, ages and educational backgrounds. Shared leadership is usually observed in ventures. Rather than confining leadership to one individual, team members can share it around based on their circumstances and viewpoints. This article demonstrates the relationships between leaders and subordinates through collaborative cooperation between leaders and members demonstrating shared leadership in incubated enterprises. By addressing the knowledge gap about shared leadership dynamics in startups in incubation, this study contributes to the corpus of literature. The investigation of supportive leader member relationships in a shared leadership environment offers valuable insights for enhancing leadership value along with encouraging dyadic workplace exchanges in startups.

Keywords: Shared Leadership, Startups, Incubation, Mutual Interactions, Team Effectiveness, Leadership Effectiveness, Leader Member Exchange,Dyad.

1. Introduction

Leadership stories mostly glorify the achievement of visionary individuals while deeming the importance of the support network encircling any great leader. These “trusted subordinates” contribute a range of skills, viewpoints, and knowledge to the table, which helps the leader perform better and promotes group success. They are more than

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just disciples (Graen & Scandura, 1987). The concept of trustworthy subordinates is theoretically predicated on the Leader Member Exchange (LMX) theory, which recognizes the unique dyadic relationships between leaders and followers (Dansereau *et al.,* 1975). According to LMX theory (Graen & Uhl-Bien, 1995), adherents actively shape their responsibilities and contribute to organisational objectives. This theory challenges traditional hierarchical frameworks. The current study used 54 firms that were at varying phases of incubation (early stage, venture funded growth stage and late stage) at an esteemed academic institution's innovation cell to investigate the relative significance of leadership within new venture teams.These teams are demonstrating shared leadership as the subjects are of similar quality, age, status and background. Shared leadership is a variety of dispersed leadership that originates from inside a team (Ensley *et al.,* 2006). In startups, the group of peers shares leadership responsibilities which leads to shared leadership. This article attempts to explore the relationships between leader and member in this shared leadership environment.

The form of dyadic interaction in such shared leadership characteristics is measured through the study of primary data collected using the Multidimensional Scale of Perceived Shared Leadership (Pearce & Sims, 2002) and the LMX-7 questionnaire by (Graen & Uhl-Bien, 1995). The Multidimensional Scale of Perceived Shared Leadership assesses team members' perceptions of shared leadership across attributes like shared objective interdependence, shared influence, and collective leadership behaviour. Respondents rate agreement with statements related to collaborative decision making and problem solving, reflecting shared responsibility and influence within the team (Pearce & Sims, 2002).While,the LMX-7 scale assesses leader member exchange quality, assessing trust, communication, and mutual respect between leaders and team members. It includes items on role clarity, contribution recognition, and affective bonds. Respondents rate agreement with statements reflecting their relationship with their leader (Graen & Uhl-Bien, 1995). The fact that these findings held for all groups suggests the importance of shared leadership in addition to the more conventional conception of vertical leadership.

Organisations are adopting innovation laboratories more frequently to capitalize on intrapreneurship.The semiautonomous teams in these creative settings challenge conventional command and control leadership models by allowing numerous members to collaboratively exercise leadership. Studies have indicated that collaborative leadership, particularly in artistic contexts, can improve team performance. In an innovation lab, this study investigates the causes of shared leadership and how it affects team creativity. Important elements for promoting shared leadership are voice, task reflexivity, and experimental culture. Data from a variety of sources, including coaches and team members, show how these elements support shared leadership and foster creativity and innovation. It is imperative that enterprises rethink their organizational settings as company incubators in order to accommodate the fast changing economic landscape. By adopting business incubation as a tactic, companies can take advantage of fresh prospects while promoting entrepreneurship, creativity, and innovation. The literature on business incubators is reviewed in this article, which also emphasizes the need for more studies on the outcomes of incubation and incubates.

2.Literature Review

2.1. Background of LMX Theory

The theory of leader member exchange was originally formulated by Graen, Novak, and Sommerkamp in 1982. The focal point of the theory is the dynamic that exists between a leader and the remaining members of an organization, team, work unit, or department. Work engagement and job performance are facilitated for employees in high quality LMX relationships and are proven as a more resourceful work environment (Breevaart *et al.,* 2015). A noteworthy and affirmative correlation was discovered among commitment, organizational performance, and leader member exchange. According to Anderson *et al.* (2014), the primary components of change are content, people, and process. The term "content" incorporates work practices, systems, technologies, and strategies. The most recent understanding explains that as the vertical dyad develops, its members cultivate strong emotional attachment, mutual respect for one another's competence, trust in one another's character, and benevolence toward one another. These individuals actively partake in team activities to promote organizational wellbeing, prosperity, and success. The central tenet of LMX theory is that leaders cultivate distinct quality relationships with each of their subordinates. That is, a leader may cultivate a poor LMX relationship with some subordinates, but a high LMX relationship with other subordinates. This assumption of relationship heterogeneity distinguishes LMX from more traditional leadership theories (e.g. trait, and behavioural theories), which assume that leaders develop homogeneous relationships with all of their members; otherwise known as an Average Leadership Style approach (Dansereau *et al.,* 1975). Several discussions postulate that the seven questions on LMX-7 might measure multiple constructs, but LMX-7 is the scale that comprises seven items. Whereas what kind of behavioural factors constitute LMX was under investigative investigation.Liden & Maslyn (1998) conducted multidimensional confirmatory factor analyses of the multidimensional factor structure for both supervisor and subordinate LMX scales and proposed four distinct dimensions: affect, loyalty, contribution, and professional respect. Additionally, results indicated that multidimensional LMX scales measured from both supervisor and subordinate perspectives predict crucial individual and organizational outcomes.

2.2. Background of Shared Leadership Theory

The intricacies of shared leadership, the prerequisites for effective implementation, the significance of communication, and the obstacles involved are all highlighted in organizational research on the subject (Anderson *et al.,* 2014; Kocolowski, 2010; Gorla & Lam, 2004; Hiller *et al.,* 2006; Koivunen, 2007; Lovelace *et al.,* 2007; O'Connell *et al.,* 2002; Pearce & Herbik, 2004; Thamhain, 2004; Wang *et al.,* 2005). Although leadership teams and collaboration in diverse sectors (e.g., healthcare and education) are the main subjects of research, shared leadership in its most fundamental form continues to be a specialized field. Coleadership in Republican Rome exemplifies the primordial origins of shared leadership, in contrast to the hierarchical leadership model that has been the prevailing structure in the majority of organizations across the globe throughout history. Historically, the perception of leadership has been centred on the individual, which has contributed to the prevalence of solitary leaders within institutions (O'Toole *et al.,* 2002). On the contrary, contemporary organizational frameworks and viewpoints acknowledge that leadership is institutional in nature as well as individual (Avolio *et al.,* 2009). The concept of shared leadership is becoming more prevalent, signifying a transition towards decentralized power structures and enhanced leadership capabilities across all levels. Shared purpose, social support, voice, joint task completion, skill development, decentralized interaction, and emotional support are fundamental elements of shared leadership (Carson *et al.,* 2007). In contrast to vertical leadership, team leadership places significant emphasis on the values of collaboration, collective decision making, and information sharing (Chen *et al.,* 2007). Team effectiveness can be increased by granting team members autonomy, involving them in decision making, and requiring them to manage themselves. McIntyre (1999) identifies the following characteristics of effective leadership teams: strategic objectives, extensive networks, collaborative relationships, streamlined information processing,and targeted action.

2.3. Leadership in Startups

Through the allocation of responsibility for leadership among team members, shared leadership deviates f rom traditional leadership paradigms and challenges the traditional single leader model (Cox *et al.,* 1991; Carson *et al.,* 2007). Within the notion of shared leadership, LMX illustrates the diverse quality of connections that exist between various members of the group (Erdogan & Bauer, 2010; Liden *et al.,* 1993). Some studies (Dienesch & Liden, 1986;

Bauer & Green, 1996) suggest that leaders should purposefully establish a variety of LMX relationships, while others associate LMX with varying degrees of leader effort. The effect of LMX differences on shared leadership is still little understood, despite its capacity to affect internal dynamics and group cohesion (Erdogan & Bauer, 2010). Social identity theory and justice assessments are combined in the Group Participation Model, which clarifies how group members' identification impacts their participation (Tyler & Blader, 2003; Tajfel & Turner, 1979; Harris *et al.,* 2014; Lind & Tyler, 1988). Members are motivated by their perceptions of justice to uphold the group's position and secure its operation (Sparrowe *et al.,* 2006). According to Van Knippenberg & Schippers (2007) and Li & Liao (2014), LMX differences can undermine equality based justice beliefs and collective team member identification by generating relational boundaries and unjustly allocating crucial resources. This practice of classifying people into in-group and out-group members can cause conflict and jeopardize the development of shared leadership and team procedures. LMX difference undermines shared leadership emergence by undermining beliefs of equality and communal identity (Tyler & Blader,2003).

2.4. Emergence of Shared Leadership in Incubations

Research on idea laboratories, accelerators, and digital labs, among other types of innovation labs, has mostly concentrated on the wider consequences of entrepreneurship and innovation from a strategic standpoint. The human aspect of these work environments, particularly the networks and coordination among intrapreneurial team members, has, however, received little consideration. The unique setting of innovation labs has been generally disregarded in team research, despite the crucial role that successful cooperation plays in lab performance. Horizontal coordination where team members share leadership behaviours rather than depending on a formal, vertical leader is necessary for innovation laboratories. So, it is essential to comprehend the efficacy of shared leadership and the elements that led to its development in innovation laboratories. A team's experimental culture, task reflexivity, and voice are examples of potential antecedents that impact shared leadership and, in turn, the creative output of the team. This study highlights important characteristics that support shared leadership in creative cooperation using a social network approach and the importance weighted density (IWD) operationalization of shared leadership. Through an examination of the distinctive features of shared leadership in a collaborative, intrapreneurial setting, this research advances our knowledge of team performance and creativity in innovation labs.

There isn't much research that focuses on shared leadership in incubation labs. Pearce & Sims (2002) demonstrated how well shared leadership works in a variety of organizational settings and indicated that incubation laboratories might be able to use it. Furthermore, shared leadership improves team performance, according to Carson *et al*. (2007). This is especially important given the dynamic and cooperative atmosphere of incubation labs. Hoch (2013) also looked at the function of shared leadership in creative teams, highlighting the significance of cooperation and reciprocal influence, two things that are vital in incubation environments. Despite these realizations, there is still a great deal to learn about the specific ways that shared leadership influences the creative processes and results in incubation labs,which calls for more research.

This study investigates stages of shared leadership and supportive leader subordinate relationships, providing valuable information for boosting leadership value and nurturing dyadic team interactions in startups.

3. Objective

The primary goal of this study is to evaluate the cooperative leader member exchange in a shared leadership environment.

4. Research Gap Identification

While shared leadership dynamics have been studied in a variety of organizational contexts, research on startup environments is scarce (Carson *et al.*, 2007; Erdogan & Bauer, 2010). There is a lack of research on cooperative LMX relationships within shared leadership environments, particularly in startup environments.The literature review identified a research gap and the necessity for empirical studies that look into shared leadership variation in startup incubators and analyze cooperative leader subordinate interactions in these settings.

5. Research Methodology

The research style used here for examining shared leadership is based on the “onion model” which focuses on a thorough and multilayered analysis of the phenomenon. Theories can be derived from empirical evidence using an inductive technique. A detailed understanding of shared leadership dynamics may be obtained by examining 54 businesses at different stages of incubation. The empirical method has its robustness which is provided by quantitative approaches. Applying validated tools such as the LMX-7 questionnaire and the Multidimensional Scale of Perceived Shared Leadership guarantees accurate and trustworthy assessment of leadership constructs, enabling nuanced understandings of leader member interactions and group leadership behaviours in entrepreneurial contexts. Here, ventures funded growth, and late, and early stage startups are considered for a thorough analysis of shared leadership across various incubation stages.

5.1. Methodology

The approach used in this research is founded on the “onion model” concept which was put forth by Saunders *et al.* (2009). The study employs a practical research ethic, emphasizing practical outcomes and real world implementations of shared leadership in companies.

5.2. Research Approach

The study employs an inductive methodology, drawing on observations and ideas from the startups under investigation to construct theories and generate fresh perspectives on the dynamics of shared leadership.

5.3. Research Strategy

The study employs an approach of examining 54 companies in the innovation cell of a prestigious academic institution at different stages of incubation (early stage, venture funded growth stage, and late stage). Using this approach, a shared leadership environment may be comprehensively examined in a practical setting.

5.4. Methodological Option

The study employs a quantitative approach, integrating strategies for gathering and analyzing quantitative data. The study makes use of two tools/ scales: A quantitative instrument for assessing team members' perceptions of shared leadership across characteristics such as sharing objective interdependence, shared influence, and collective leadership behaviour is the Multidimensional Scale of Perceived Shared Leadership (Pearce & Sims, 2002). LMX-7 questionnaire (Graen & Uhl-Bien, 1995): A quantitative tool to assess the level of trust, communication, and respect that leaders and team members have for one another.

5.5. Techniques and Procedures

The Multidimensional Scale of Perceived Shared Leadership and the LMX-7 questionnaire are the main tools used to acquire data from team members of the startups under study. The quantitative techniques used in the data analysis procedures will include statistical tests and analyses to investigate the connections between team performance, leader member interchange,and shared leadership.

6. Resultsand Findings

6.1. Study-1

The Multivariate Analysis of Variance (MANOVA) test is used to evaluate the effects of the mean average LMX score, which

Table 1: Levene's Test for Equality of Variances Was Done to Assess the Equality of Variances:

Variable	F-value	P-value
Shared Goal	2.56	0.110
Interdependence	3.05	0.050
Shared Influence	1.97	0.162
Collective Leadership	2.10	0.123

Source: Author's Compilation

Inference: Since all p-values are above 0.05, we assume equal variances across groups for all dependent variables.

is calculated from the Leader LMX and Member LMX scores for each subject of shared leadership in a corporate context. The MANOVA results for the impact of the mean LMX score depend on the five variables such as collaborative decision making, shared goal, interdependence, shared influence, and collective leadership behaviour which are provided below (Table 1).

Tests of Between Subjects Effects to provide

Table 2: Multivariate Tests (Pillai's Trace, Wilks' Lambda, Etc.) Here Summarizes the Overall Model Fit:

Test	Value	F-statistic	df1	df2	p-Value
Pillai's Trace	0.45	4.22	4	50	0.0001
Wilks' Lambda	0.55	4.88	4	50	0.0008
Hotelling's Trace	0.82	5.15	4	50	0.0035
Roy's Largest Root	0.80	5.33	4	50	0.0011

Source: Author's Compilation

Inference: The test is significant ($p < 0.001$), indicating that changes in the mean LMX score significantly affect the combined dependent variables

Table 3: Tests of Between Subjects Effects Provide Results for Each Dependent Variable Separately:

Dependent Variable	Type III Sum of Squares	df	Mean Square	F-value	P-value
Shared Goal	23.56	4	5.89	4.10	0.003
Interdependence	30.24	4	7.56	5.00	0.001
Shared Influence	28.17	4	7.04	4.75	0.002
Collective Leadership	26.80	4	6.70	4.55	0.002

Source: Author's Compilation

Inference: All p values are less than 0.05, indicating significant effects of the leadership qualities on each team outcome.

results for each dependent variable separately:

According to the MANOVA, changes in the mean LMX score had a substantial impact on all aspects of shared leadership studied. Effective LMX relationships can foster team wide cohesive and productive leadership behaviours.

Equation: Shared leadership= $\beta 0+\beta 1 \times$Mean LMX+ϵ

According to the MANOVA results presented, the conclusions can be summarized as follows:

The study looked at how the mean LMX score, which was calculated by combining the Leader LMX and Member LMX scores of each subject in a shared leadership context, affected several aspects of shared leadership in a corporate setting. The MANOVA analysis showed that the mean LMX score had a significant overall effect on the dependent variables: collaborative decision making, shared goal, interdependence, shared influence, and collective leadership behavior (Pillai's Trace = 0.45, F = 4.22, $p < 0.001$) (Table 2). The evaluations of between subject effects revealed significant individual impacts of the mean LMX score on each of the common leadership characteristics. Shared goals (F = 4.10, p = 0.003), interdependence (F = 5.00, p = 0.001), shared influence (F = 4.75, p = 0.002), and collective leadership behavior (F = 4.55, p = 0.002) (Table 3). These findings indicate that changes in the mean LMX score, which measures the level of trust, communication, and respect between leaders and team members, have a significant impact on the various dimensions of shared leadership within teams. Effective leader member exchange connections encourage team wide coherent and productive leadership behaviours, establishing a common awareness of goals, interdependence, shared influence, and collective leadership. As a result, developing positive LMX connections within teams can help to ensure the successful implementation of shared leadership approaches in corporate environments.

The leader member interchange score correlates well with all aspects of shared leadership. Any solid relationship would serve as the foundation for all successful leadership results by a team member acting as a leader or member in any situation. Whether someone is taking on leadership or fellowship, the key source of strength is positive interaction and relationships inside the workplace.

6.2. Study-2

A Spearman rank correlation analysis is used to determine the association between shared leadership and LMX ratings at different stages of startup incubation (Table 4). This nonparametric test was chosen because it may analyze monotonic correlations between variables without assuming linear relationships, which is appropriate for the exploratory nature of the investigation.

The Spearman rank correlation analysis finds significant positive correlations between

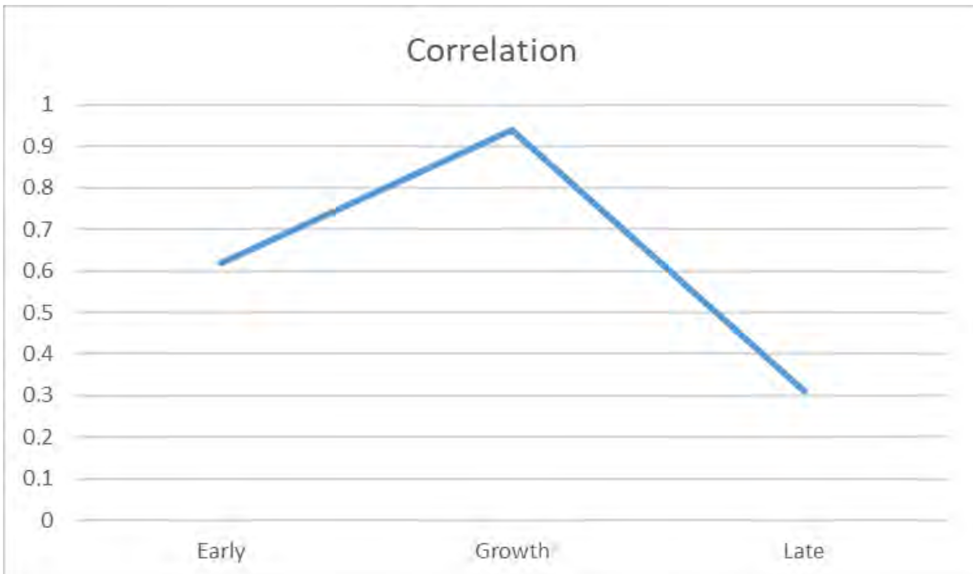
Table 4: Correlation Table

Stage of Incubation	Mean LMX	Shared Leadership Score	Correlation	Significance (2-tailed)
Early	17	20	0.62	$p < 0.01$
Growth	22	50	0.94	$p < 0.01$
Late	21	35	0.31	$p < 0.05$

Source: Author's Compilation

Inference: Strong correlations between shared leadership and LMX, emphasizing its pivotal role in fostering effective leader member relationships across stages.

Figure 1: Correlation Variation Across Stages of Incubation of Startups



Source: Author's Compilation

shared leadership and LMX evaluations at various stages of firm incubation, emphasizing their importance in developing effective team dynamics (Figure 1). The interplay between shared leadership and LMX at different stages of startup incubation is depicted here. The table shows mean LMX scores and shared leadership levels, as well as Spearman rank correlation coefficients and significance levels (2-tailed) for the early, growth, and late stages. The findings show that shared leadership and LMX have varied associations at different stages of incubation. Significant positive associations, especially during the expansion stage, demonstrate the importance of shared leadership in cultivating high quality leader member interactions. These findings underscore the need for adaptive leadership tactics customized to distinct periods of incubation in improving organizational dynamics and performance.

7.Discussion

Leader Member Exchange (LMX) quality has a major impact on the establishment of shared leadership in incubation labs. High LMX promotes shared leadership through open communication, mutual respect, and trust. Cooperative goal setting, interdependence, shared influence, and collective leadership behaviours are enhanced by strong LMX interactions and are essential for productive team dynamics and innovation (Carson *et al.,* 2007). As an organization grows, strong LMX linkages are essential for resilience and peak performance, but as the organization becomes more complicated, their influence may change. Consequently, to maintain team effectiveness and innovation during several incubation phases, adaptable leadership tactics are required. These results highlight how crucial it is to have solid LMX connections to promote shared leadership in innovation or incubation, which agrees with the findings of (Pearce & Sims, 2002) in different work settings.

7.1. Leader Member Exchange and Shared Leadership

The study emphasizes how important leader member interaction (LMX) is to encourage shared leadership approaches in businesses. The significance of productive leader follower relationships is highlighted by the positive correlation found between mean LMX scores and different facets of shared leadership. Shared leadership thrives in high quality LMX partnerships, which are marked by open communication,mutual respect,and trust.

7.2. Multidimensional Impact of LMX

The results show that LMX has a substantial impact on a number of shared leadership aspects, such as cooperative goal setting, interdependence, shared influence, and collective leadership behavior. This multifaceted effect implies that solid LMX relationships promote the growth of team members' shared knowledge, interdependence, and collective influence, which in turn promotes cooperative decision making processes.

7.3. Fostering Shared Goals and Interdependence

Teams that have strong LMX ties are better able to establish common objectives and a sense of interdependence. High quality interactions between leaders and followers increase the likelihood that they will align goals and acknowledge their dependency on accomplishing group goals, which fosters the growth of shared leadership.

7.4. Promoting Shared Influence and Collective Leadership

According to the study, LMX connections that are constructive help teams develop shared influence and collaborative leadership behaviours. To promote collective leadership practices, strong leader follower interactions enable team members to exert influence and participate in leadership processes.

7.5 Stage Wise Leadership Dynamics Throughout the Incubation Process

Strong positive correlations during the growth stage emphasize the pivotal role of shared leadership in fostering high quality leader member relationships, crucial for startup success. However, the weaker correlation observed in the late period suggests a complicated relationship, possibly influenced by evolving organizational complexities. This discussion emphasizes the need for adaptive leadership strategies tailored to various incubation phases. By understanding and leveraging these insights, startups can cultivate resilient team dynamics and optimize organizational performance from inception to maturity.

7.6. Implications for Corporate Environments

The results hold significance for establishments aiming to adopt shared leadership methodologies, especially in professional contexts. Through proactive cultivation of strong LMX relationships based on open communication, mutual respect, and trust building, businesses can foster an atmosphere that facilitates shared leadership and optimizes the combined strengths of team members.

8. Conclusion and Future Scope

The findings of this study highlight the critical role of leader member interaction (LMX) in promoting the use of shared leadership strategies in corporate settings. The relationship between average LMX scores and various aspects of shared leadership, such as collaborative decision making, shared goals, interdependence, shared influence, and collective leadership behaviour, highlights the importance of encouraging effective interactions between leaders and followers. Organizations can create an environment that encourages shared leadership and leverages their employees' unique capabilities by promoting open communication, trust, and mutual respect among teams. This technique allows them to achieve long term success in today's fast changing business environment. This study examines how shared leadership and LMX interact differently at different stages of a startup's incubation. Good positive correlations shown throughout the growth stage demonstrate the importance of shared leadership in creating good leader member relationships, which are critical to an organization's success. On the other hand, the association in the later stage indicates that environmental factors have an impact on this dynamic interaction. These findings show the importance of flexible leadership strategies designed for specific incubation stages. Startups can use these insights to successfully navigate challenges, build strong team dynamics, and maximize organizational performance as they mature. This research helps enhance startup management practices by offering valuable insights into effective leadership tactics and team dynamics. Gaining insight into the variability of shared leadership and cooperative interactions in startup environments helps improve leadership development programs and foster more collaborative work cultures, eventually promoting the success and long term viability of firms.

Further studies might look into the long term effects of shared leadership on startup success and growth. Examining contextual aspects, such as the type of industry and company structure, may help us better understand how shared leadership works in different startups. Furthermore, performing comparative analysis at various stages of startup development may highlight the changing nature of shared leadership dynamics over time.

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Impact of Wetland Pollution on Fish Diversity

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Abstract

Aquatic ecosystems provide a wide range of ecological services, such as the provision of food, fodder, and water, remediating contaminants, moderating microclimate, providing cultural services, etc., which sustain the livelihoods of dependent populations. However, aquatic ecosystems are in peril throughout the world due to unplanned developmental activities leading to changes in land cover, sustained inflow of untreated or partially treated domestic sewage and industrial effluents, climate change, introduction of exotic or alien species, overexploitation, habitat modification, and degradation. Native fish species production in inland wetlands has been significantly contributing to the regional economy through food security, nutrition, employment creation, and the reduction of poverty.The fisheries sector significantly contributes to global food security, nutrition, and livelihoods, ensuring economic prosperity, sustainable food systems, and biodiversity as per the United Nations Sustainable Development Goals. In this context, the current research presents fish diversity along with the water quality in the urban lakes of the Bangalore city.The linkages between fish diversity and water quality parameters were assessed through canonical correspondence analysis (CCA). The study reveals that the degradation of aquatic habitats has affected native species' fish diversity and production, which has impacted the livelihood of the fishing community due to impaired ecosystem services. Hence, there is an urgent need to formulate strategies for promoting conservation to sustain fish diversity and productivity and support the livelihood of people.

Keywords: Lakes, Fish, Water Pollution, Diversity,Ecosystem Services.

1. Introduction

Aquatic ecosystems offer essential

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provisioning, regulating, and cultural services to the dependent population and sustain the livelihood of the vulnerable sections of society (Ramachandra *et al.,* 2024; Sincy *et al.,* 2024). Fish production from inland wetlands significantly contributes to food and economic security by providing animal protein, essential nutrients, and income (Ramachandra *et al.,* 2022). Diverse fish species provide easily digestible proteins, vitamins, minerals, and polyunsaturated fatty acids and hence play a significant role in regional socioeconomic growth (Maulu *et al.,* 2021). Fish production contributes 1.24 per cent to the country's gross value added (GVA) and over 7.28 per cent to agricultural GVA, according to the economic survey for 2021–22. The transition from capture to culture based fisheries in inland aquatic ecosystems has enabled India to sustain a blue economy (National Fisheries Development Board,2023).

The 2030 Agenda for Sustainable Development, adopted by all UN agencies, outlines seventeen Sustainable Development Goals (SDGs), three of which are particularly relevant in the context of aquatic ecosystems (Duarah & Mall, 2020): Goal-1 (no poverty), Goal-2 (zero hunger), and Goal-12 (sustainable consumption and production). Freshwater fishes are the most diversified group of vertebrates in the world, but they are also the most endangered due to unplanned developmental activities like urbanization, dam construction, irrigation, industry, water pollution, etc. The global database Fish Base 2023 lists 35,332 species spread across 5,198 genera, 623 families, 84 orders, and 10 classes, and there are 1010 species in freshwater aquatic ecosystems in India.

Fish diversity in an aquatic ecosystem provides insights about habitat conditions and aids in monitoring ecosystem health over longer periods of time, and fish are often referred to as bioindicators (Tabrez *et al.,* 2022; Mahamood *et al.,* 2021). Low species biodiversity indicates potential environmental pollution in the aquatic ecosystem (Rasyad *et al.,* 2020). As aquatic habitats are influenced by climatic regimes (air temperatures and precipitation patterns), fish are highly susceptible to climate change (Makki *et al.,* 2023). Fish assemblage in a particular aquatic ecosystem is dependent on habitat conditions reflecting physical and chemical factors, such as water level fluctuation, water velocity, stream order, bottom substrate, turbidity, conductivity, pH, and dissolved oxygen (Menon *et al.,* 2023; Soo *et al.,* 2021; Svobodova *et al.,* 1993). The interplay and fluctuations of temperature, pH, and precipitation over the elevational gradient determine the composition or assemblage of freshwater fish species (Roy *et al.,* 2021). Freshwater ecosystems have become vulnerable due to emerging anthropogenic factors, such as sustained inflow of untreated wastewater from domestic and industrial sectors, unplanned rapid urbanization, industrialization, increasing water extraction, habitat degradation, overexploitation, invasive species introduction, water diversions, etc., which will have wide ranging deleterious effects on the life cycle, distribution, and composition of freshwater fish (Sincy *et al.,* 2022; Beltrán-López *et al.,* 2023), necessitating inventorying and recording fish diversity and water quality in aquatic ecosystems. The literature review highlights scant information on fish diversity in lakes in Bangalore city, which necessitated monitoring lakes to compile fish related information. The current study focuses on (a) water quality monitoring of select urban lakes, (b) evaluation of fish diversity, (c) a review of the fisheries sector in India (the Blue Revolution), and (d) the effect of water pollution on fish diversity and economic values. The outcome of the research aids in identifying major risks to biodiversity, which would aid in developing policy strategies and plans for prudent management measures to protect aquatic habitats.

2.Materialsand Methods

2.1. Study Area

Greater Bangalore, which spans 741 square kilometres (situated 920 meters above mean sea level) is located between latitudes 12° 49' 5" N and 13° 08' 32" N and longitudes 77° 27' 29" E and 77° 47' 2" E. It serves as the major administrative, cultural, economic, industrial, and knowledge capital of the Karnataka state. The undulating terrain of Bangalore city has three watersheds, namely the Hebbal-Nagavara, Koramangala-Challaghatta, and Vrishabhavathi watersheds. The temperature in summer ranges from 18°C to 38°C, while during winter, it ranges from 12°C to 25°C. In the current study, 36 lakes in Greater Bangalore (Figure 1) are being monitored for water quality and the diversity of fish (Ichthyofauna).

2.2. Fish Sample Collection

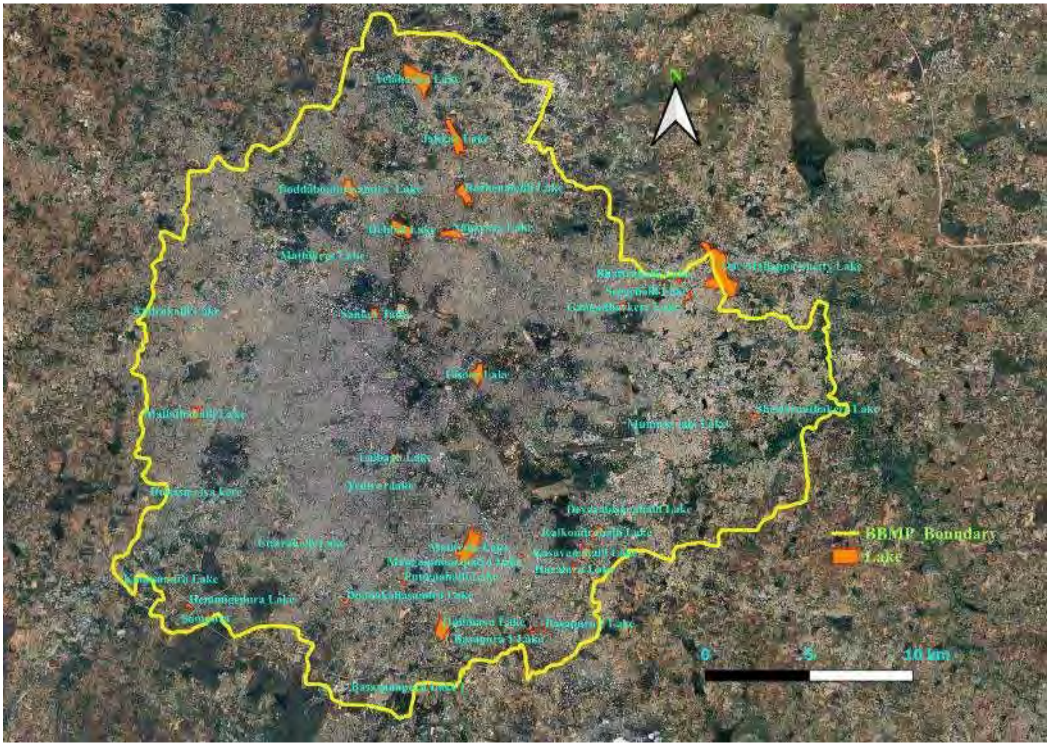
Fish specimens were collected from lakes with the help of local fishermen using gill nets or cast nets. The location of the sampling of species occurrences is recorded using the Garmin Etrex Global Positioning System (GPS). The collected fish specimens were identified at the species level using morphological keys and standard literature. The unidentified specimens were preserved in a 10 per cent formaldehyde solution. Taxonomic analysis was conducted using standard keys, reference books (Jayaram, 1999; Talwar & Jhingran, 1991), and an online data portal, Fish Base. Open-source GIS software QGIS[4] was used for spatial analyses of various fish orders in 36 lakes in Greater Bangalore.

2.3. Water Sample Collection and Laboratory Analyses

Water samples from 36 lakes were collected

[4]https://qgis.org

Figure 1: Bangalore City with the Spatial Distribution of Lakes



Source: Authors' Compilation

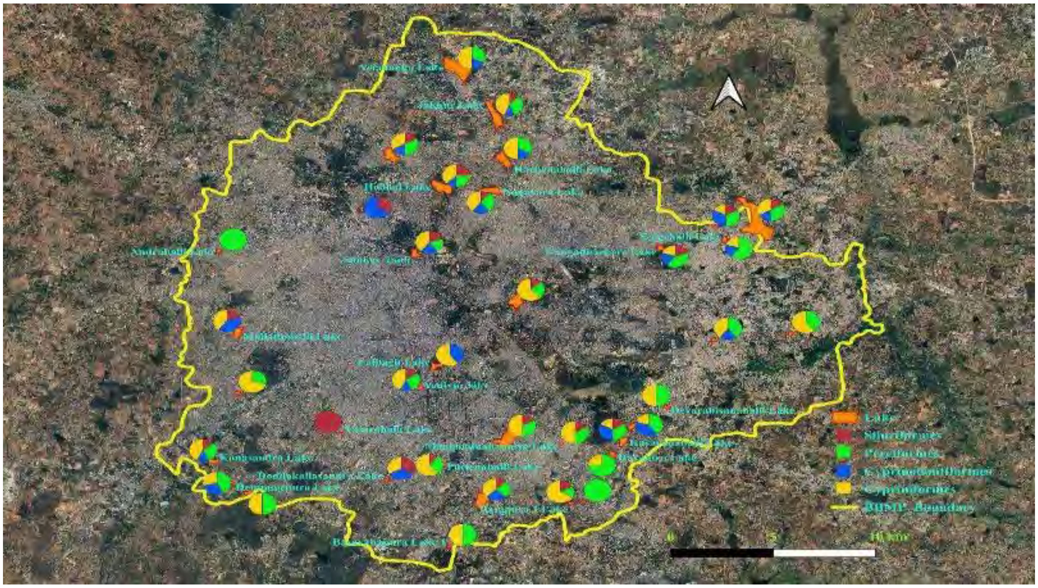
for physicochemical analysis between 2018 and 2020. Parameters such as water temperature (WT), dissolved oxygen (DO), pH, and total dissolved solids (TDS) were measured in the field using a portable meter (Extech), while other parameters such as total hardness (TH), total alkalinity (TA), chemical oxygen demand (COD), biochemical oxygen demand (BOD), turbidity, orthophosphate (OP), and nitrate (Nit) were estimated in the EWRG, IISc aquatic laboratory through the standard protocol of APHA (2012).

2.4. Statistical Analysis

Fish assemblages and environmental characteristic linkages were assessed through multivariate Canonical correspondence analysis (CCA) through PAST3 software[5].

[5]https://past.en.lo4d.com/download

Figure 2: Fish Composition (Order Wise) in Urban Lakes of Bangalore City



Source: Authors' Compilation

CCA has been carried out to understand the linkages between species assemblages with the condition of ecosystems. The technique aids in extracting significant environmental gradients from ecological data sets (Soo *et al.,* 2021; Arumugham *et al.,* 2023; Cheng *et al.,* 2019) and the relationship follows Gaussian distribution. Predominant fish orders (Cypriniformes, Perciformes, Cyprinodontiformes, and Siluriformes) and 11 environmental variables (water temperature, total dissolved solids, pH, total alkalinity, total hardness, turbidity, dissolved oxygen, orthophosphate, nitrate, chemical oxygen demand, and biochemical oxygen demand) of respective habitats were utilized to perform the canonical correspondence analysis.

3. Results and Discussion

3.1. Ichthyofauna Diversity of Lakes

The current study documented a total of eighteen freshwater fish species from four orders, seven families, and fourteen genera in 36 monitored lakes in Bangalore city. Data analyses revealed that Cypriniformes are the most dominant, followed by Perciformes, Cyprinodontiformes, and Siluriformes in the monitored lakes of Bangalore city (Figure 2). The species composition of the order

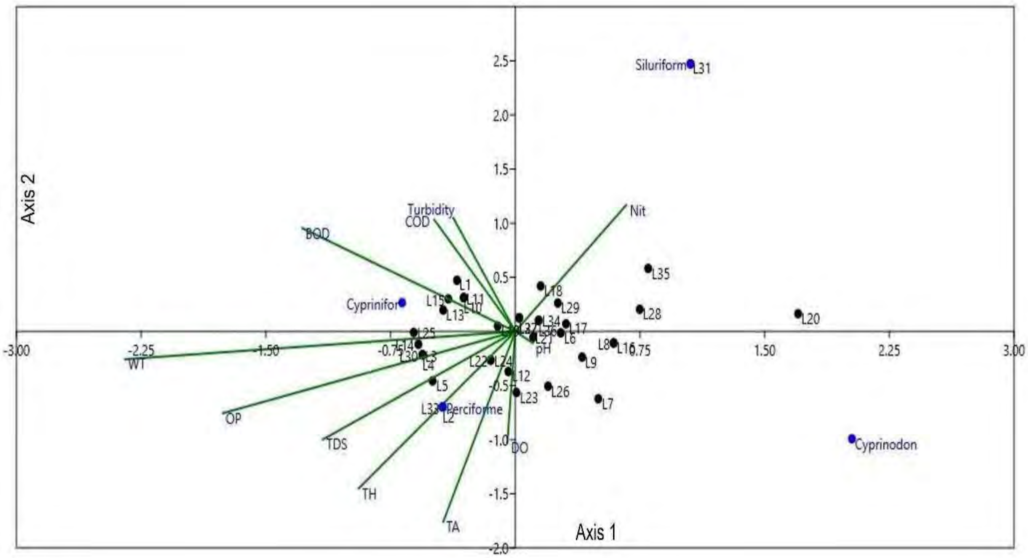
Cypriniformes is *Catla catla, Labeo rohita, Ctenopharyngodon idella, Cyprinus carpio, Cirrhinus mrigala, Labeo fimbriatus, Puntius ticto, and Hypophthalmichthys molitrix.* Cyprinodontiformes include *Gambusia affinis and Poecilia reticulata*. Perciformes consist of *Oreochromis mossambicus, Oreochromis niloticus, Channa punctata, Channa striata,* and *Parambassis ranga, and Siluriformes* consist of *Clarias gariepinus, Clarias batrachus,* and *Heteropneustes fossilis.*

Canonical correspondence analysis (CCA), considering fish assemblages and eleven environmental parameters, highlights that fish distributions and assemblages are influenced by environmental conditions, which include the physical and chemical integrity of habitats. Here, two axes were considered based on eigenvalue and percent of variance. Axis 1 had a 65.02 per cent correlation, while Axis 2 had a 25.24 per cent correlation (Figure 3).

Figure 3 shows the significance of a physicochemical variable, its correlations with the axis, and blue dots indicating fish order in the sampled lakes. Axis 1 is positively correlated with Cyprinodontiformes and negatively correlated with Cypriniformes, water temperature, TDS, BOD, and OP. Axis 2 is positively correlated with Siluriformes, turbidity, COD, and nitrate, while it is negatively correlated with Perciformes, total hardness, total alkalinity, and dissolved oxygen. The turbidity of aquatic ecosystems aids fish in three ways: protecting juvenile fish from predators, promoting food abundance, and facilitating migration. However, high water turbidity negatively impacts fish egg survival, hatching success, feeding efficiency, growth rate, and population size (Phan *et al.*, 2020). CCA analyses reveal that DO (dissolved oxygen), water velocity and pH significantly impacted the fish assemblage structure in the Mechi River (Adhikari *et al.*, 2021). The physicochemical properties of water, such as temperature, transparency, velocity, pH, DO, CO_2 (carbon dioxide), and hardness, have a substantial impact on the quantity and richness of species (Pokharel *et al.,* 2018).

Fish spawning, growth, metabolism, breeding, and development are all influenced by temperature since they are poikilothermic (Corum *et al.*, 2023), and the ideal pH range is 6.5 to 8.5.The primary factors contributing to pollution and biodiversity loss at Betwa sites were excess nitrite, total hardness, and turbidity (Dubey *et al.*, 2013). Nutrient concentration increases can lead to the growth of phytoplankton, which eventually die and are decomposed by microorganisms, causing anoxia and large fish and aquatic life deaths due to the high rates of organic matter decomposition. Low dissolved oxygen (DO) levels in water induce stress, leading to poor appetite, delayed growth, illness susceptibility, and death in fish species (Abd El-Hack *et al.*, 2022). *Catla catla, Labeo rohita, Cirrhinus mrigala, Poecilia reticulata, Oreochromis mossambicus, Oreochromis niloticus, Clarias*

Figure 3: The Canonical Correspondence Analysis (CCA) Triplot Between Fish Composition and the Physicochemical Parameters of Urban Lakes



Note: Physicochemical parameters: water temperature (WT), dissolved oxygen (DO), pH, total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), chemical oxygen demand (COD), biochemical oxygen demand (BOD), turbidity, orthophosphate (OP), and nitrate (Nit). Fish orders: Siluriformes (Siluriform), Cyprinodontiformes (Cyprinodon), Perciformes (Perciforme), and Cypriniformes (Cyprinifor). Lake names: Basapura 1 Lake: L1; Basapura 2 Lake: L2; Basavanapura Lake 1: L3; Devarabisanahalli Lake: L4; Haraluru Lake: L5; Hulimavu Lake: L6; Kaikondrahalli Lake: L7; Kasavanahalli Lake: L8; Lalbagh Lake: L9; Madivala Lake: L10; Mangammanapalya Lake: L11; Munnekolala Lake: L12; Puttenahalli Lake: L13; Sheelavanthakere Lake: L14; Ulsoor Lake: L15; Bhattrahalli Lake: L16; Gangadharkere Lake: L17; Hebbal Lake: L18; Jakkur Lake: L19; Mathikere Lake: L20; Nagavara Lake: L21; Rachenahalli Lake: L22; Seegehalli Lake: L23; Yelahanka Lake: L24; Dubasipalya Lake: L25; Hemmigepura Lake: L26; Konasandra Lake: L27; Mallathahalli Lake: L28; Sankey Lake: L29; Sompura Lake: L30; Uttarahalli Lake: L31; Yediyur Lake: L32; Andrahalli Lake: L33; Doddabommasandra Lake: L34; Doddakallasandra Lake: L35; Yele Mallappa Shetty Lake: L36.

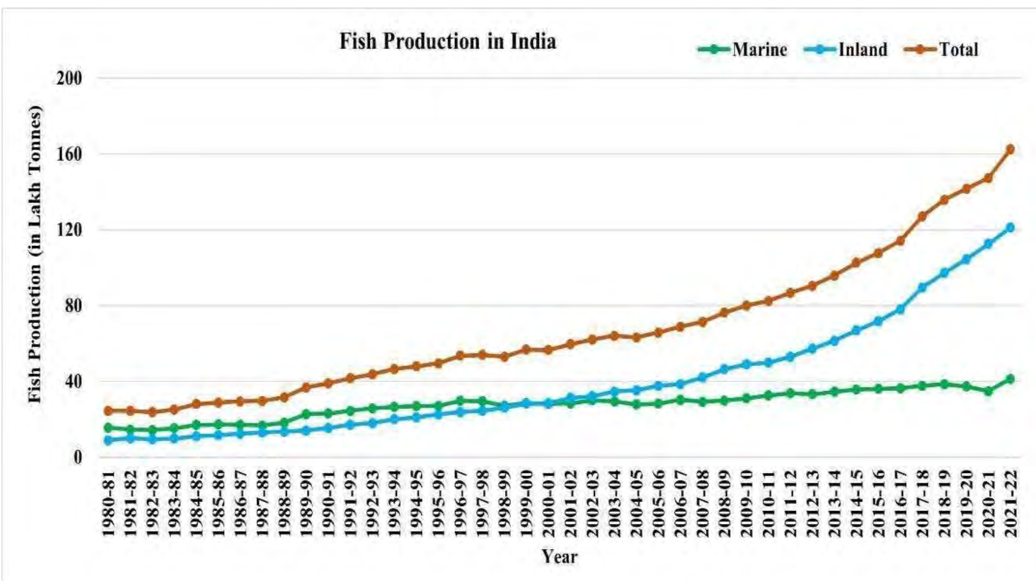
Source: Authors' Compilation

gariepinus, Clarias batrachus, and Heteropneustes fossilis are omnivores. Omnivores have a wide range of diets but primarily rely on detritus. Omnivores, located at the base of the trophic structure, are most tolerant of degradation or ecosystem dysfunction. As degradation intensifies, it leads to the disappearance of insectivores and piscivores, followed by benthic insectivores, general insectivores, planktivores, and omnivores (Wichert & Rapport, 1998). The study confirms that environmental parameters, including DO, TDS (total dissolved solids), pH, transparency, nitrate, phosphate, hardness, and alkalinity, influence the fish assemblage pattern (Sarkar *et al.,* 2020).

3.2. Blue Revolution in India

The Indian Blue Revolution is expected to contribute significantly to the Indian economy through the fish and aquaculture sectors. India is the world's second-largest producer of aquaculture and the third-largest producer of fish, accounting for 8 per cent of fish produced worldwide. The total fish production during 2021–2022 was 16.24 million tons, of which 4.12 million tons are marine fish and 12.12 million tons are aquaculture (the Ministry of Fisheries, Animal Husbandry, and Dairying, 2023). According to an economic survey, the fisheries sector in India provides employment to over 28 million people and generates export earnings of 466 billion rupees in 2019–2020. India's overall fish production was dominated

Figure 4: The Graph Shows Fish Production in India from 1980 to 2022 (Handbook Fisheries Statistics 2023)



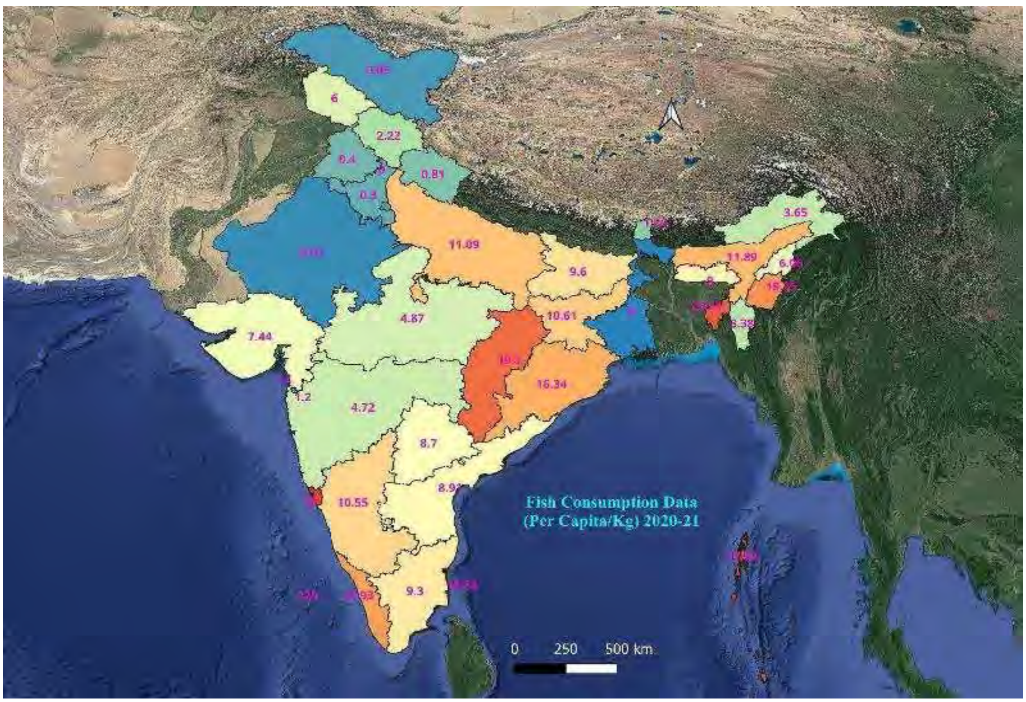
Source: Authors' Compilation

by marine fish production until 2000 (Department of Fisheries, GoI). A paradigm shift has occurred in Indian fisheries, with inland fisheries taking the lead in contributing to fish production, which increased from 36 per cent in the mid-1980s to 70 per cent in the most recent period (Figure 4).

Fish is consumed on average at 6.31 kilograms per person in India. Figure 5 depicts the statistics on fish consumption per capita per kilogram for 2020–21 across many Indian states. The annual fish consumption accounts for 10.55 kg per person in Karnataka State.

Poverty in the fishing community is primarily due to large family sizes, a lack of fishing gear, and limited employment opportunities (Kumar *et al.,* 2018). The Pradhan Mantri Matsya Sampada Yojna (PMMSY), approved by the Indian government in May 2020, aims to boost fish production by seven million tonnes, increase aquaculture productivity from 3 tonnes per ha to 5 tons per ha, double exports from Rs. 46,589 crores to Rs. 100,000 crores, create over 55 lakh job opportunities,

Figure 5: Fish Consumption Data (per Capita/Kg) 2020-21 (Handbook Fisheries Statistics, 2023)



Source: Authors' Compilation

and double fishermen and fishing communities' incomes to boost economic growth.The PMMSY, which has invested Rs. 20,050 crores, aims to address productivity gaps, infuse innovation, enhance post harvest infrastructure, modernize the value chain, and establish a framework for effective fisheries management and fishermen's welfare. Fish production has gained impetus with PMMSY evident from a fish production of 162.48 lakh metric tons, compared to 141.64 lakh metric tons in 2019–20 (Ministry of Fisheries, Animal Husbandry,and Dairying,2023).

3.3. Water Pollution Affects Fish Health and Its Economic Value

Inland water, including ponds, lakes, rivers, streams, canals, and dams, significantly supports the livelihood of people and socio-economic development. Variations in the physical, chemical, and biological integrity of freshwater ecosystems would lead to an unfavourable habitat, impacting the fish life cycle. Freshwater aquatic ecosystems are impacted by different sources of pollutants that come from mining operations, air deposition, land based runoff from urban and agricultural regions, and direct industrial discharges (Arthington *et al.,* 2016).

Conservation planning needs to focus primarily on preserving species diversity and enhancing ecosystem services.The diversity of the ichthyofauna in Bangalore has drastically decreased recently (from 55 species in the 1970s to 18 species in 2020) due to the failing ecological status of aquatic ecosystems in Bangalore due to unplanned senseless urbanization leading to encroachment of lakes, loss of interconnectivity among lakes, sustained inflow of untreated industrial effluents and domestic wastewater, habitat loss or degradation, introduction of exotic invasive fish species, flooding, and overfishing (Sincy *et al.,* 2022). Fish diversity is threatened by overfishing, climate change effects, siltation, increased agricultural production, natural droughts, urbanization, and water pollution (Pandit *et al.,* 2021).

The fish provide various goods and services, as evident from the annual provisioning service provided by fish from wetlands, which is worth INR 32,175 per hectare (Ramachandra *et al.,* 2021). The rise in pollution and habitat degradation is leading to a decline in the economic worth of freshwater ecosystems, evident from INR 20 per hectare per day in the contaminated Amruthalli Lake in Bangalore and INR 10,435 per hectare per day in the pristine Rachenahalli Lake (Ramachandra *et al.,* 2011). The profuse growth of invasive exotic species led to the decline of native species, resulting in the reduction of the economic worth of fish in Varthur Lake in Bangalore due to the sustained inflow of pollutants and the rapid growth of macrophytes (Ramachandra *et al.,* 2011). In Ulsoor Lake, Devarabisanahalli Lake, and Sankey Lake, a sudden drop in dissolved oxygen levels brought on by sewage inflow led to asphyxiation and, ultimately, fish death (Ramachandra *et al.,* 2016; Benjamin *et al.,* 1996). The depletion of oxygen caused by the vast proliferation of cyanobacteria was the cause of the significant mortality of fish and other aquatic life (Zhang *et al.,* 2022). Additionally, local fisheries are suffering economically due to the decline of native, diverse fish species and the prevalence of non-native species in lakes (Giannetto & Innal, 2021). Aquatic invasive species outcompete native species, resulting in severe biodiversity loss, health risks, and economic losses, all impacting ecosystem services (Singh,2021).

Lakes in Bangalore city are consistently undergoing degradation due to the sustained disposal of large volumes of raw or partially treated sewage, municipal solid waste (including construction and demolition debris), untreated industrial effluents, and the encroachment of storm water drains and lake beds, etc. Degradation of ecological conditions in lakes is evident from eutrophication and heavy metal contamination of biota (Ramachandra *et al.,* 2020a). Water pollution significantly impacts wetland goods and services due to declining fish productivity and food quality, impacting the livelihood of dependent populations, which necessitates an immediate restoration of ecological status by decontaminating lakes and regulating pollutants entry to the lake to enhance the ecological quality of lakes and ensure favourable habitat conditions for native aquatic species to maximize aquatic biodiversity and livelihood prospects in fragile lake ecosystems (Ramachandra *et al.,* 2020b).

4.Conclusion

The fisheries sector is crucial for global food security, nutrition, livelihoods, and promoting economic growth and sustainability. The study documented 18 freshwater fish species from four orders, 07 families, and 14 genera in the monitored 36 urban lakes in Greater Bangalore, with Cypriniformes being the most dominant order, followed by Perciformes, Cyprinodontiformes, and Siluriformes. The sustained inflow of contaminants (untreated sewage and industrial effluents), habitat loss and degradation, the introduction and culture of invasive exotic species, and overexploitation of aquatic resources are the major threats to urban lakes, leading to the decline of the diversity of freshwater fish and productivity. Changes in biotic and abiotic variables have a major impact on the distribution and richness of fish populations in aquatic ecosystems. CCA analyses reveal that declining environmental factors impact fish species and their habitats. Fish production plays a major role in socio economic development. Fish offer food security since they are a great source of animal protein and other nutrients and a significant source of income and employment. Contaminating aquatic ecosystems has contributed to a decrease in ecosystem services. The rapid degradation of freshwater ecosystems, increasing water scarcity in Bangalore, and declining fish biodiversity necessitate urgent conservation and restoration measures.

Fish are ideal for studying phenotypic differentiation at species and population levels, with ecological diversification, habitat fragmentation, and long term geographical isolation potentially contributing to population differentiation. Lakes in urban areas are undergoing severe stress due to unplanned developmental activities leading to the catchment degradation and sustained inflow of untreated sewage and industrial effluents, which have altered the physical and chemical integrity. In this regard, the current study provides a baseline information for prudent management of aquatic ecosystems to sustain the livelihood of dependent, vulnerable sections of society in Bangalore. However, the limitation of the current study is non-inclusion of all drivers of changes in the physical and chemical integrity with the biological diversity.

Scope for further research includes (a) assessment of heavy metal contamination of water bodies with the disposal of industrial effluents on fish diversity and accumulation of heavy metals in fish tissues, (b) investigations across seasons to understand the seasonal variability of fish diversity, (c) barcoding of fish species to strengthen fish diversity database.The lack of a database on freshwater fish in wetlands and target species (barcode) reference databases has been the major drawback for biodiversity analyses, necessitating the development of various strategies to overcome these limitations.

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Supply Chain Risk and Resilience in the Textile Industry

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Abstract

This study provides a thorough analysis of the textile industry's supply chain risk and resilience, with a focus on assessing the sector's ability to adjust to and recover from disruptions. The textile sector faces various problems in the context of today's dynamic business environment, which is characterized by unpredictability and deep global interdependencies. These challenges call for a strong and resilient supply chain. This assessment includes a thorough examination of crucial supply chain components, the determination of risk factors, and the development of efficient mitigation measures. There are three objectives for this study. To understand their current situation, it first seeks to evaluate the supply networks' resilience within the textile industry. In addition, it looks for weaknesses and dangers that have a big impact on how the sector runs its supply chains. It also aims to create workable methods that can strengthen supply chain resilience in the event of shocks, ensuring the industry's ongoing growth. To do the analysis, we have adopted a triangular fuzzy approach. The findings highlight that adopting three stage process of primary, secondary and tertiary calculations, how organizations can identify their level of resilience. In the present study it is found to be just resilient and have further scope to improve towards very resilient and extremely resilient categories.

Keywords: Supply Chain Risk, Supply Chain Resilience, Textile, Responsiveness, Triangular Fuzzy.

1. Introduction

Today, supply chains are undergoing undesirable situations, which expose the companies to stock out conditions and disruptions. The cost, quality and availability of inputs define the outputs; however, the activities of the supply chain offer several opportunities for catching the risk starting from procurement to distribution of products. It can range from events like COVID-19, earthquakes, hurricanes and geopolitical conflicts (Simchi-Levi *et al.,* 2014; Modgil *et al.,* 2022). Each node of the supply chain ranging f rom supplier, manufacturer, distributor to retailer is prone to supply chain disruption (Pettit *et al.,* 2010). Therefore, it is important for the supply chains to develop their capacity to tolerate and recover from

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disturbances, while performing its routine jobs (Christopher & Peck, 2005; Rice & Caniato, 2003). The importance of supply chain resilience is much more when it comes to industries like textiles, where raw materials are imported and exported worldwide. The industry is susceptible to disruptions caused by events like natural catastrophes, political unrest and trade conflicts. Apart from this, the competitive landscape is also putting pressure on the industry to keep the cost down and supply chain effective.The industry of textiles has r i sks spread across suppliers, transportation and logistics to the demand as well. Hence to strengthen the resilience companies are diversifying their supplier base to reduce their reliance on a single source, strengthening the supplier relationships and optimizing the inventory (Gupta *et al.,* 2022). However, the question remains how to identify the level of resilience of an organization and how to find the gaps if any for enhancing the resilience of a company. Therefore, this study focuses on showcasing how the level of resilience of an organization can be measured and how weaker attributes can be tackled further to enhance the level of resilience.

The rest of the manuscript is organized as follows. The second section discusses the literature review, the third section highlights the methodology, and the findings and analysis are presented in section four. The conclusion is presented in section five.

2.Literature Review

2.1 Supply Chain Risk and Resilience

Supply chain risk encompasses the potential disruptions that can impact the flow of goods and services in a supply chain. The supply chain risks can be of five types: demand risk, supply risk, operational risk, environmental risk, and financial risk. On the other hand, supply chain resilience refers to the capacity of a supply chain to anticipate, prepare for, respond to, and recover from disruptive situations. Ponomarov & Holocomb (2009) define the supply chain resilience as the adaptive capability of the supply chain to prepare itself to continue its operations and have control over the different functions of the supply chain. The risk management process involves identifying, assessing, and developing effective risk management strategies (Tang, 2006). Studies have explored how companies manage the supply chain risk and explore to build the supply chain resilience. For example, Rice & Caniato (2003) have studied Dell and Nokia, and how they maintain their inventories to fulfil the market demand. Another study by Pettit *et al.* (2010) explored, how Proctor and Gamble developed the supply chain which is competent and risk robust. Focusing and developing risk management capabilities also help companies to perform better while employing proactive risk management practices (Zsidisin & Ellram, 2003). Having adequate supply chain resilience impacts both the operational and financial performance of the company (Wieland & Wallenburg, 2013). The supply chains need to invest in developing technologies, strengthening relationships and strategic sourcing to enhance their risk and resilience capabilities.

2.2 Risk Mitigation Strategies

The risk mitigation strategies include the strategies and actions taken to minimize the impact of potential disruptions. Strategies of risk mitigation can be classified as avoidance, reduction, sharing and retention (Tang, 2006). The risk in the supply chain involves both general and exceptional risks, where continuous risk assessment is necessary. The risk management integration into the supply chain is the base for supply chain resilience. The risk avoidance involves the elimination of activities that put the supply chain at risk. For instance, avoiding single source procurement can help in mitigating the supplier risk. Similarly reducing risk can minimize the impact of risk. For instance, the emphasis on quality assurance and quality control to reduce operational risks (Chopra & Sodhi, 2004). Other studies have highlighted the risk sharing with other stakeholders through partnership. For example, forming a strategic alliance to share financial risk (Wagner & Bode, 2008). Another way to mitigate and plan for risk is to accept and make budgetary provisions for the potential losses. For instance, to have a contingency fund for potential disruptions (Tang, 2006). Empirical studies and events have highlighted different risk mitigation strategies. For example, Toyota's strategy of having multiple suppliers helped them survive the 2011 tsunami in Japan. In another example, Cisco collaborates with suppliers to assess the risk and enhance the supply chain visibility. Companies are investing in the blockchain and other Industry 4.0 technologies to improve transparency and traceability and minimize the risk of fraud (Kshetri,2018).

3.Methodology

The methodology adopted in this study consists of three steps. Figure 1 highlights the steps involved.

Step 1: First, the factors that are critical to achieving a level of resilience are identified with the help of literature. Table 1 highlights the main four factors i.e. Flexibility, Redundancy,Visibility and Collaboration.

Step 2: Further the factors are divided into sub-factors as presented in Table 1.

Step 3:

Primary Calculation

$$RLij = \sum_{k=1}^{N} Wijk * Rijk \,/ \sum\nolimits_{k=1}^{N} Wijk$$

Where RLij = Resilience level of jth criteria in ith enabler

Rijk = Performance rating of kth attribute in jth criterion in ith enabler

Table 1: Resilience Key Factors and Sub-Factors and Their Weights

S.No.	Factor	Weight	Sub-factor
1	Flexibility	VH	Flexibility in production
			Level of customization
			Workforce skill level
			Flexibility in contract management
			Flexibility of sourcing
			Flexibility of distribution
2	Redundancy	H	Additional capacity
			Stock capability
			Backup utility
3	Visibility	VH	Information sharing
			Tracking of information among activities
			Business intelligence
			Real time information flow
4	Collaboration	H	Collaborative demand forecasting
			Joint decision making
			Joint investment

Source: Kamalahmadi *et al.,* 2022

Wijk= Importance weight of kth attribute in jth criterion in ith enabler.

Secondary Calculation

$$RLi = \sum_{i=1}^{N} Wij * RLij \,/ \sum_{i=1}^{N} Wij$$

Where Wij= Importance weight of jth criterion in ith enabler

RLi = Resilience level of ith enabler

RLij = Resilience level of jth criteria in ith enabler

Tertiary Calculation

$$FRI = \sum_{i=1}^{N} Wi * RLi \,/ \sum_{i=1}^{N} Wi$$

Step 4: Euclidean Distance between FRIi and RL

$$D(FRI, RL) = \{\sum (fFRI(x) - fRL(x))^2\}^{\frac{1}{2}}$$

4.Analysis and Findings

Table 2 presents the primary, secondary and tertiary calculations, whereas Tables 3, 4 and 5 present the Linguistic Variables, performance rating, weights and finally we calculate the distance between the Fuzzy Resilience Index and Resilience Level as highlighted in Table 6.

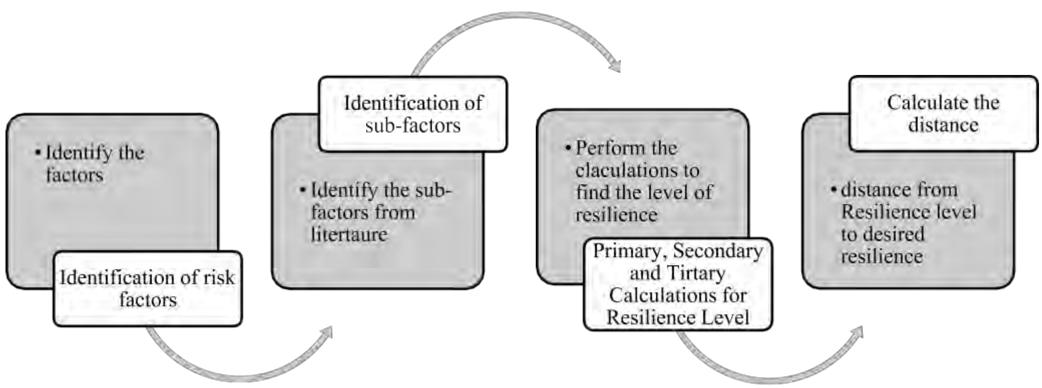
After calculating the distance between Linguistic Variables and the Fuzzy Resilience Index, we have got the following result in Table 6.

Table 6 highlights that after performing step four, the level of the supply chain is just resilient and still has scope to further develop the capabilities to move towards very resilient and extremely resilient categories.

5.Conclusion

This study explores the case study of an organization from the textile industry, and how the supply chain of the organization is operating. At the current level, it is just resilient, which may not be sufficient to tackle the complex disruptions. The frequent assessment of the resilience level helps organizations to align their resources and ensure product amid chaos. The current level of resilience presents the ability of the organization to recognize and address the four key factors and sub-factors. To improve further, the organization should assess the gaps and plan for improving the current

Figure 1: Methodology Adopted



Source: Author's Compilation.

Table 2: Calculation of Fuzzy Resilience Index

Step 1 Primary Assessment(Flexibility)						
0.5	0.65	0.8	*	5	6.5	8
0.3	0.5	0.7	*	3	5	7
0.3	0.5	0.7	*	3	5	7
0.5	0.65	0.8	*	5	6.5	8
0.7	0.8	0.9	*	7	8	9
0.7	0.8	0.9	*	7	8	9

ΣW*R	16.6	26.25	38.8
ΣW	3	3.9	4.8
LC1	5.533333	6.730769	8.083333

Step 1 Primary Assessment(Redundancy)						
0.3	0.5	0.7	*	3	5	7
0.5	0.65	0.8	*	5	6.5	8
0.3	0.5	0.7	*	3	5	7

ΣW*R	4.3	9.225	16.2
ΣW	1.1	1.65	2.2
LC2	3.909090	5.590909	7.363636

Step 2 Secondary Assessment						
0.85	0.95	1	*	5.533333	6.730769	8.083333
0.7	0.8	0.9	*	3.909090	5.590909	7.363636
0.85	0.95	1	*	.54545454	.31081081	.07692307
0.7	0.8	0.9	*	.53333333	.73076923	.08333333

ΣW*LC	13.47666	20.34684	28.06252
ΣW	3.1	3.5	3.8

FRI	4.347311	5.813383	7.384876

Step 1 Primary Assessment(Visibility)						
0.2	0.35	0.5	*	2	3.5	5
0.3	0.5	0.7	*	3	5	7
0.3	0.5	0.7	*	2	3.5	5
0.3	0.5	0.7	*	3	5	7

ΣW*R	2.8	7.975	15.8
ΣW	1.1	1.85	2.6
LC3	2.545454	4.310810	6.076923

Step 1 Primary Assessment(Colaboration)						
0.5	0.65	0.8	*	5	6.5	8
0.3	0.5	0.7	*	3	5	7
0.7	0.8	0.9	*	7	8	9

ΣW*R	8.3	13.125	19.4
ΣW	1.5	1.95	2.4
LC3	5.533333	6.730769	8.083333

Source: Author's Compilation.

Table 3: Table of Linguistic Variables of Resilience with Fuzzy Numbers

Resilience Level	Fuzzy No.		
Extremely Resilient (ER)	7	8.5	10
Very Resilient (VR)	5.5	7	8.5
Resilient (R)	3.5	5	6.5
Fairly Resilient(FR)	1.5	3	4.5
Slighly Resilient (SR)	0	1.5	3
FRI			

Source: Vidyadhar *et al.,* 2016

Table 4: Table of Linguistic Variables on Performance Rating of Resilience with Fuzzy Numbers

Linguistic variable	Fuzzy no (Rij)		
Performance Rating			
Worst (W)	0	0.5	1.5
Very Poor (VP)	1	2	3
Poor (P)	2	3.5	5
Fair (F)	3	5	7
Good (G)	5	6.5	8
Very Good (VG)	7	8	9
Excellent (E)	8.5	9.5	10

Source: Vidyadhar *et al.,* 2016

Table 5: Table of Importance Rating of Resilience with Fuzzy Numbers of Weights

Importance Rating	Fuzzy No. (Wij)		
Very Low (VL)	0	0.05	0.15
Low (L)	0.1	0.2	0.3
Fairly Low (FL)	0.2	0.35	0.5
Medium (M)	0.3	0.5	0.7
Fairly High (FH)	0.5	0.65	0.8
High (H)	0.7	0.8	0.9
Very High (VH)	0.85	0.95	1

Source: Vidyadhar *et al.,* 2016

situation. Further, to continue this study the organization can consider multiple criteria decision making approaches where the ranking of the improvement factors can be calculated and further brainstormed. Further, studies can be conducted to adjust the resilience level and resource alignment with the level of uncertainty in the business environment.

Table 6: Distance Matrix between Linguistic Variables and Fuzzy Resilience Index

		SQRT	
D(FRI,ER)	114.0190513	10.67797037	
D(FRI,VR)	44.26905131	6.653499178	
D(FRI,R)	27.73094869	5.266018296	Best
D(FRI,FR)	75.73094869	8.702353055	
D(FRI,SR)	95.98094869	9.796986715	5.266018296

Source: Author's Compilation

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