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RIPPLE EFFECT OF THE RECESSION OF AMAZONIAN RIVERS ON THE SUPPLY LOGISTICS OF COMMERCE IN BENJAMIN CONSTANT (AM)

RIPPLE EFFECT DAS VAZANTES DOS RIOS AMAZÔNICOS NA LOGÍSTICA DE SUPRIMENTOS DO COMÉRCIO EM BENJAMIN CONSTANT (AM)

RIPPLE EFFECT DE LA BAJANTE DE LOS RÍOS AMAZÓNICOS EN LA LOGÍSTICA DE SUMINISTROS DEL COMERCIO EN BENJAMIN CONSTANT (AM)

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RESUMO

Purpose: To examine how the *Ripple Effect*, which propagates disruptions throughout Supply Chains, is intensified by the seasonality of Amazonian rivers, impacting the supply logistics of commerce in Benjamin Constant (AM) and directly affecting the local economy and population.

Design/methodology/approach: A qualitative, exploratory-descriptive study was conducted through a case study in a Commercial Association, using non-participant observations, unstructured and semi-structured interviews, and documentary analysis, with a content analysis approach.

Findings: River seasonality intensifies the *Ripple Effect*, increasing logistical costs, compromising operational efficiency, and limiting modal alternatives. Strategies such as safety stock, smaller vessels, and interorganizational collaboration proved effective but were constrained by financial and structural limitations. The findings reinforce logistics resilience theories, emphasizing the importance of adaptive strategies in contexts with limited infrastructure. Furthermore, the lack of effective public policies exacerbates the challenges faced by merchants and consumers, affecting supply chains and the cost of living

Research limitations / implications: The sampling, limited to one municipality and three merchants, restricts the generalization of findings. Future studies should replicate the research in other regional contexts to broaden its scope. Practical implications include the need for public policies to promote modal diversification and strengthen logistics resilience. Additionally, the study contributes to the literature by expanding the understanding of the Ripple Effect in vulnerable regions and reinforcing the importance of logistics resilience.

Originality / value: This study explores the *Ripple Effect* in Supply Chains within the Amazonian context, an underexplored area, providing insights applicable to public and private managers focused on enhancing the region's logistics resilience in the face of climate change.

Keywords: *Ripple Effect*. Supply Chain Logistics. Hydrological Seasonality. Logistics Resilience.

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ABSTRACT

Objetivo: Examinar como o *Ripple Effect*, que propaga disrupções ao longo de Cadeias de Suprimentos, é intensificado pela sazonalidade dos rios amazônicos, impactando a logística de suprimentos do comércio em Benjamin Constant (AM), afetando diretamente a economia e a população local.

Desenho/metodologia/abordagem: Realizou-se estudo qualitativo e exploratório-descritivo, por meio de estudo de caso em Associação Comercial, utilizando observações não participantes, entrevistas não estruturadas e semiestruturadas, e análise documental, com abordagem de análise de conteúdo.

Resultados: A sazonalidade dos rios intensifica o *Ripple Effect*, aumentando custos logísticos, comprometendo eficiência operacional e limitando alternativas modais. Estratégias de estoques de segurança, embarcações menores e colaboração interorganizacional mostraram-se eficazes, mas restritas por limitações financeiras e estruturais. Os achados reforçam teorias de resiliência logística, destacando a importância de estratégias adaptativas em contextos de infraestrutura limitada. Além disso, a ausência de políticas públicas eficazes agrava as dificuldades dos comerciantes e consumidores, afetando o abastecimento e o custo de vida.

Limitações/implicações da pesquisa: A amostragem restrita a um município e três comerciantes limita a generalização dos achados. Sugere-se replicar o estudo em outros contextos regionais para ampliar sua abrangência. As implicações incluem a necessidade de políticas públicas para diversificação modal e fortalecimento da resiliência logística. Além disso, sua implicação contribui para a literatura, ampliando a compreensão do *Ripple Effect* em regiões vulneráveis e reforçando a importância da resiliência logística.

Originalidade/valor: Explora o Ripple Effect das Cadeias de Suprimentos em contexto amazônico pouco estudado, trazendo insights aplicáveis aos gestores públicos e privados voltados à resiliência logística da região diante das mudanças climáticas.

Palavras-chave: *Ripple Effect*. Logística de Suprimentos. Sazonalidade Hídrica. Resiliência Logística.

RESUMEN

Objetivo: Examinar cómo el *Ripple Effect*, que propaga disrupciones a lo largo de las Cadenas de Suministro, se intensifica debido a la estacionalidad de los ríos amazónicos, impactando la logística de abastecimiento del comercio en Benjamin Constant (AM) y afectando directamente la economía y la población local.

Diseño/metodologia/enfoque: Se realizó un estudio cualitativo y exploratorio-descriptivo mediante un estudio de caso en una Asociación Comercial, utilizando observaciones no participantes, entrevistas no estructuradas y semiestructuradas, y análisis documental con un enfoque de análisis de contenido.

Resultados: La estacionalidad de los ríos intensifica el *Ripple Effect*, aumentando los costos logísticos, comprometiendo la eficiencia operativa y limitando las alternativas modales. Estrategias como el almacenamiento de seguridad, el uso de embarcaciones menores y la colaboración interorganizacional resultaron efectivas, aunque restringidas por limitaciones financieras y estructurales. Los hallazgos refuerzan las teorías de resiliencia logística, destacando la importancia de estrategias adaptativas en contextos con infraestructura limitada. Además, la ausencia de políticas públicas eficaces agrava las dificultades de los comerciantes y consumidores, afectando el abastecimiento y el costo de vida

Limitaciones/Implicaciones de la investigación: La muestra restringida a un municipio y tres comerciantes limita la generalización de los hallazgos. Se recomienda replicar el estudio en otros contextos regionales para ampliar su alcance. Las implicaciones prácticas incluyen la necesidad de políticas públicas que promuevan la diversificación modal y el fortalecimiento de la resiliencia logística. Además, este estudio contribuye a la literatura ampliando la comprensión del *Ripple Effect* en regiones vulnerables y reforzando la importancia de la resiliencia logística.

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Originalidad/Valor: Explora el Ripple Effect en Cadenas de Suministro dentro del contexto amazónico, un área poco estudiada, proporcionando conocimientos aplicables a gestores públicos y privados interesados en mejorar la resiliencia logística de la región frente al cambio climático.

Palabras clave: *Ripple Effect*. Logística de Suministro. Estacionalidad hídrica. Resiliencia Logística.

INTRODUCTION

Supply Chain Management (SCM) is a strategic field that involves the efficient coordination of all activities required to produce and deliver products to consumers (Hugos, 2018; Chopra & Meindl, 2013). Its evolution from a linear structure to interdependent networks reflects the increasing complexity of logistics operations, particularly in vulnerable contexts, which demand greater adaptability. Climate change has tested the effectiveness of SCM in addressing the challenges posed by disruptive events (Yun & Ülkü, 2023; Freeman, 2023). The ability of Supply Chains (SC) to withstand, respond to, and recover from disruptive events may become a key attribute for ensuring business sustainability (Zavala-Alcívar et al., 2020).

In this context, the *Ripple Effect*, which describes the propagation of disruptions throughout supply chains, has received increasing attention (Dolgui & Ivanov, 2021). This phenomenon undermines logistical performance by amplifying the impacts of localized interruptions—such as the low water levels of Amazonian rivers—leading to higher costs and reduced operational efficiency (Dolgui et al., 2018). Factors such as low inventory levels, reliance on a single mode of transportation, lack of contingency planning (Ivanov, 2018; Dolgui et al., 2018), economic collapse, epidemics, natural disasters, and political instability (Hsu et al., 2022; Kumar et al., 2023) have been identified as amplifiers of this effect.

The Amazon region, due to its near-exclusive reliance on waterways, offers a unique setting for studying the impacts of the *Ripple Effect*. Inland waterways, which account for 86% of local logistical operations (Nogueira & Oliveira, 2019), are highly sensitive to seasonal river fluctuations. During the dry season, supply chains face severe challenges, such as the inability of large vessels to navigate, the need for adaptive transport using smaller boats (e.g., canoões), increased logistical costs, and loss of product quality (Garcia, 2022). Furthermore, these logistical constraints have direct implications for the quality of life of local populations, who depend on these systems for the supply of essential goods.

Although the in urban and industrial supply chains is extensively covered in the literature (Dolgui et al., 2018; Ivanov, 2018; Zavala-Alcívar et al., 2020), few studies examine this phenomenon in vulnerable regions with limited infrastructure, such as the Amazon. Moreover, research on the interplay between resilience practices—such as robustness, flexibility, and redundancy (Zavala-Alcívar et al., 2020; Dolgui et al., 2018)—and interorganizational collaboration (Yun & Ülkü, 2023; Shekarian & Parast, 2020) remains scarce in contexts marked by extreme seasonality and climate change impacts. This theoretical gap hinders a comprehensive understanding of local dynamics and impedes the development of effective strategies to mitigate the effects of seasonal river fluctuations. By empirically investigating how local traders cope with the logistical disruptions triggered by the *Ripple Effect*, this study offers an applied analysis that can inform both public policy formulation and logistical management in regions facing unique challenges.

This paper seeks to address this gap by examining how the Ripple Effect, which propagates disruptions along supply chains, is intensified by the seasonal fluctuations of Amazonian rivers, affecting supply logistics in the municipality of Benjamin Constant (AM), with direct consequences for the local economy and population. The research investigates the disruptions caused by the *Ripple Effect* and the mitigation strategies adopted by local merchants, aiming to identify practical solutions to foster regional logistical resilience.

To this end, a qualitative, exploratory-descriptive study was conducted through a case study of a Commercial Association. The research employed non-participant observations, unstructured and semi-structured interviews, and docu-

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ment analysis, using a content analysis approach. This methodological choice is justified by the need to gain an in-depth understanding of the logistical dynamics and challenges faced by merchants in response to the disruptions caused by the *Ripple Effect*, thereby enabling a detailed examination of the resilience strategies required in a context of limited infrastructure.

The findings of this study indicate that river seasonality intensifies the *Ripple Effect* by increasing logistical costs, reducing operational efficiency, and limiting modal alternatives. Strategies such as the formation of safety stock, the use of smaller vessels, and interorganizational collaboration have proven effective, yet remain constrained by financial and structural limitations. Furthermore, the absence of specific public policies aimed at improving infrastructure and promoting modal diversification exacerbates the challenges faced by merchants, directly impacting the local economy and the population's cost of living. These findings reinforce theories on logistical resilience and highlight the need for adaptive strategies to mitigate the impacts of seasonality on supply chain flows.

The conclusions of this study underscore the importance of logistical resilience strategies to mitigate the impacts of supply chain disruptions in vulnerable regions. By offering solutions applicable to such contexts, the research contributes not only to strengthening the operational resilience of local stakeholders but also to informing public policy aimed at modal diversification and the improvement of logistical infrastructure. Moreover, by integrating the concepts of the *Ripple Effect* and logistical resilience within a setting characterized by extreme seasonality, this study expands the theoretical understanding of how supply chains adapt to scenarios marked by uncertainty and structural constraints.

Accordingly, in addition to this introduction, the paper is organized into four more sections. Section 2 presents the Theoretical Framework, discussing core concepts related to SCM, the *Ripple Effect*, logistical resilience, and the specific characteristics of supply chains in vulnerable contexts. Section 3 outlines the Methodological Procedures, detailing the research design as well as the data collection and analysis methods. Section 4 provides the Presentation and Discussion of Results, highlighting the main findings and their connection to the existing literature. Section 5 offers the Conclusions, linking the study's findings to the research propositions. Finally, Section 6 presents the Final Considerations, emphasizing the theoretical and practical contributions of the study, its limitations, and suggestions for future research.

THEORETICAL FRAMEWORK

Supply Chain Management (SCM): Concepts, Importance, and Challenges

Supply Chain Management (SCM) constitutes a strategic component for business success, as it involves the efficient coordination of all activities required to produce and deliver products to consumers (Hugos, 2018; Chopra & Meindl, 2013). Precisely for this reason, effective SCM practices yield a significant competitive advantage, which in turn directly enhances organizational performance (Cahyono et al., 2023; Hwihanus et al., 2022; Siahaan et al., 2020), fostering a shift from traditional and reductionist views of SCM toward more dynamic and integrated approaches (Wieland, 2021).

Climate change has increasingly tested the effectiveness of SCM in addressing the challenges posed by *disruptive events*, which threaten supply chain efficiency and heighten the vulnerability of organizational operations. These climatic changes significantly impact supply chain resilience by increasing the frequency and intensity of *extreme weather events*, which disrupt logistics networks, delay the flow of goods, and raise operational costs (Yun & Ülkü, 2023; Freeman, 2023). Furthermore, climate change reduces the availability of natural resources and raw materials, leading to more frequent stockouts, higher inventory costs, and bottlenecks in procurement, manufacturing, and logistics functions (Kara et al., 2020; Bašić et al., 2024). In light of this, organizations must acknowledge the vulnerability of their supply chains to climate change and develop strategies to mitigate the associated risks (Yun & Ülkü, 2023).

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In the Amazon region, climate change has led to recurring droughts that increase the risk of cascading tipping point events by exceeding adaptive capacities (Wunderling et al., 2022). This has significantly affected organizational operations, as rivers serve as critical "highways" connecting various parts of the region—particularly in areas where terrestrial infrastructure is lacking (Rodrigues et al., 2025). As a result, there is a broad dependence on river transport, which accounts for up to 86% of logistics operations in some cases (Nogueira & Oliveira, 2019). Consequently, local supply chains become especially vulnerable to adverse climatic conditions (Rodrigues et al., 2025), such as the receding water levels of the Solimões and Javari rivers, which compromise navigable routes and increase logistics costs by up to 45% (Garcia, 2022). This context underscores the need for resilience practices tailored to the specific characteristics of regions like the Amazon.

Ripple Effect: Impacts and Propagation

The *Ripple Effect* is a specific area of disruptions and a significant stress factor for supply chain resilience, widely present in organizational practice and having attracted considerable research interest in recent years (Dolgui & Ivanov, 2021). The Ripple Effect occurs when a disruption, instead of remaining localized or contained within a part of the supply chain, propagates downstream, affecting performance and altering the structural dynamics of the chain (Dolgui et al., 2018). Such disruptions occur at certain nodes within a supply chain, spread to "neighboring companies," and eventually impact the entire network, leading to significant operational efficiency issues (Li & Zobel, 2020; Llaguno et al., 2021; Korder et al., 2022).

Disruptions caused by the *Ripple Effect* can propagate due to various factors, such as economic collapse, epidemics, natural disasters, and political factors (Hsu et al., 2022; Kumar et al., 2023). More specifically, the literature identifies at least three sustainability factors that either mitigate or amplify the *Ripple Effect* in the supply chain: 1) the sustainable use of a single source of supply increases the *Ripple Effect*; 2) fortification of facilities in major employers in certain regions mitigates the *Ripple Effect* and enhances sustainability; and 3) reductions in downstream storage facilities within a supply chain at risk of disruption increase sustainability but also cause the *Ripple Effect* (Ivanov, 2018). Other studies further highlight four basic reasons for the increased impact of disruptions on the execution and performance of supply chains: s*ingle sourcing, low safety stock, full utilization of production capacity*, and the *absence of contingency plans* (Dolgui et al., 2018).

In the Amazon, the most significant challenges faced by supply chain managers are related to distribution, economic issues, and disruptions in supply and demand (Tadaiesky et al., 2022). These problems may be amplified by river seasonality, where low water levels render certain river routes impassable, thereby exacerbating the *Ripple Effect*. This has forced local merchants to adopt more costly and less efficient logistical alternatives, such as using smaller vessels or increasing stock levels (Garcia, 2022), significantly impacting the resilience of local supply chains. However, reliance on a single mode of transport and the lack of intermodal integration (Nogueira & Oliveira, 2019) may further aggravate the impacts of disruptions, limiting the available response options to the phenomenon. It is important to recognize that different resilience practices adopted to manage disruptions may not be equally effective for disruptions that propagate differently (Birkie & Trucco, 2020), justifying scientific investigations that produce theoretical constructs and managerial applications contextualized to specific environments.

Supply Chain Resilience: Mitigating the Ripple Effect

The mitigation of the *Ripple Effect* becomes possible through the implementation of backup or dual sourcing policies, flexible and reconfigurable production and logistics systems, risk-mitigating inventories, coordinated contingency policies, and physical security technologies (Dolgui et al., 2018). These measures ensure a *Resilient Supply Chain*, enhancing its ability to handle disruptions and unforeseen events, thereby minimizing the impacts of such disturbances on the continuity of operations. The ability of supply chains to withstand, respond to, and recover

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from disruptive events can become a key characteristic for maintaining business sustainability (Zavala-Alcívar et al., 2020).

To enhance SC resilience against disruptions, key elements include flexibility, redundancy, and robustness (Zavala-Alcívar et al., 2020; Dolgui et al., 2018). *Flexibility* and *redundancy*, reinforced by the principle of supply chain robustness, most effectively minimize the consequences of a disruption within the system (Zavala-Alcívar et al., 2020).

Redundancy plays a crucial role in achieving SC resilience. Elements such as alternative sources of supply and contingency stocks provide robustness to the supply chain, enabling it to maintain planned performance even in the face of disruptions. Furthermore, *flexibility* is essential for the SC's ability to adjust and change in response to internal and external challenges, ensuring its resilience over time. Therefore, SC resilience is built on *redundancy* for *robustness* and *flexibility* to adapt to and recover from disruptions, maintaining the continuity of operations and achieving management objectives (Dolgui et al., 2018).

The resilience of the SC to the *Ripple Effect* also depends on the presence of redundancies such as inventory buffers and reserve capacities, as well as on the speed and scope of recovery actions. This underscores the importance of assessing risks and incorporating resilience considerations from the design and planning stages (proactivity). In the event of a disruption, it is crucial to promptly activate contingency plans, such as employing alternative suppliers or transportation routes, during the control phase (reactivity). These measures ensure rapid stabilization and recovery, thereby preventing long-term impacts and maintaining an uninterrupted supply flow (Dolgui et al., 2018).

Collaboration is also crucial for managing control disruptions and enhancing the overall *resilience* of the SC (Yun & Ulku, 2023; Shekarian & Parast, 2020). This highlights the need for closer cooperation among different SC nodes to effectively mitigate risks (Shekarian & Parast, 2020). Collaboration and partnerships play an essential role in building *resilient supply chains*, while also fostering *sustainable supply chains* (Yun & Ulku, 2023), including risk prevention, supply chain integration, and a focus on economic, social, and environmental sustainability (Zhu & Wu, 2022). Building SC resilience through sustainability practices may indirectly enhance organizational performance (Zhu & Wu, 2022), in a complex and non-linear relationship. Although both concepts are interrelated, resilience does not always improve at the same pace as sustainability, underscoring the need for integrated approaches (Freeman, 2023; Bezares et al., 2021).

Theoretical Propositions

Supply chains face increasing challenges in regions characterized by climatic and structural vulnerabilities, such as the Amazon, where seasonal events and reliance on a single mode of transportation amplify disruptions. In this context, the *Ripple Effect* emerges as a disruptive force that undermines logistical efficiency and exposes operational weaknesses, demanding resilience practices that integrate flexibility, redundancy, and robustness, as well as interorganizational collaboration to mitigate its impacts. Based on the literature review, this study presents the following theoretical assumptions:

- *Proposition 1:* The seasonal fluctuations of rivers in the Amazon intensify the *Ripple Effect*, leading to increased logistical costs and diminished operational efficiency

- *Proposition 2:* Integrated strategic practices, such as flexibility, redundancy, and robustness, partially mitigate the impacts of the *Ripple Effect*, fostering resilience in vulnerable regions.

- *Proposition 3:* Interorganizational collaboration is essential for overcoming structural limitations and fostering resilience in contexts such as the Amazon.

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METHODOLOGICAL PROCEDURES

Characterization and Research Method

This study is characterized as *exploratory--descriptive*, a choice justified by the need to investigate a scarcely explored phenomenon – the *Ripple Effect* in the context of the seasonal low water levels of the Amazon rivers – and to describe its specific characteristics. The *exploratory approach* allowed for a deeper understanding of the research problem (Gil, 2002), mapping its conditions of manifestation (Severino, 2007), in this case, the dynamics and disruptions of SC's in a unique regional context, aiming to define the theoretical propositions of this study and increasing researchers' familiarity with the phenomenon (Marconi & Lakatos, 2018). This approach is considered appropriate for this case due to the scarcity of empirical studies investigating the effects of the *Ripple Effect* in vulnerable regions like the Amazon, where climatic and seasonal factors play a central role in supply chain logistics.

In turn, the descriptive *approach detailed* the core characteristics of the phenomenon (Gil, 2002), without inferring causal relationships between the studied variables, but rather describing the reality of the object and providing support for a more in-depth analysis (Appolinário, 2001). This approach ensured the systematization of the collected data, enabling the identification and categorization of the challenges faced by local traders and the resilience strategies adopted.

The *case study* method was adopted as the primary approach for this research, given its suitability for deepening the understanding of complex and contextual issues (Yin, 2015). This method allows for a focused examination of the phenomenon under investigation, temporarily subordinating other questions so that the accounts of those who "experience the case" can reveal relevant insights (Stake, 2000). Accordingly, the study was conducted at the Association of Micro and Small Enterprises in Commerce, Industry, and Service Provision of Benjamin Constant (AMPEC-IPS), an organization that brings together approximately fifty local merchants directly impacted by the low water levels of the Solimões and Javari rivers. The choice of this association is based on its representativeness within the municipality's commercial sector, encompassing a diverse range of merchant profiles, and its relevance as a focal point for local collaborative practices. The analysis of logistical resilience within this entity required a detailed investigation of the local dynamics, the strategies adopted by the agents, and the impact of logistical disruptions.

Data Sample

The research employed *purposive sampling*, selecting three merchants from AMPEC-IPS based on specific criteria: direct involvement in commercial operations affected by the river low--water periods (20 members), active membership in AMPEC-IPS (ten members), and a minimum of ten years of experience in the sector (ten members). Table 1 details the participants, presenting their areas of operation, roles performed, and years of experience, ensuring they possess the knowledge and practical experience essential for understanding the phenomenon under study. These profiles were carefully selected to ensure that the perspectives analyzed would be representative of the conditions faced by merchants in Benjamin Constant.

Table 1
Interviewees' Professional Profile.

Interviewee	Age	Business	Position in the company	Time in position
Interviewee 1 (I1)	47	Retail trade of general merchandise (Grocery store)	Owner	20 years
Interviewee 2 (I2)	35	Retail trade of general merchandise (Supermarket)	Manager	10 years
Interviewee 3 (I3)	49	Retail trade of general merchandise (Grocery store)	Owner	22 years

Source: Elaborated by the authors (2024).

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Data Collection, Treatment, and Analysis

Data collection was conducted using multiple techniques, ensuring a comprehensive and triangulated approach:

a) *Non-Participant Observations*: These were carried out during a general assembly of AMPEC-IPS and in informal discussions within online messaging groups. Such observations enabled the capture of organizational and collaborative dynamics that might not be accessible through other research instruments.

b) *Semi-Structured Interviews*: Conducted virtually with three AMPEC-IPS merchants, each lasting approximately 60 minutes. All interviews were recorded with the participants' consent and subsequently transcribed for analysis. A semi-structured script was employed, allowing for flexibility to explore relevant topics based on the interviewees' responses.

c) *Unstructured Interview*: Conducted in person with a representative of the local Civil Defense agency, lasting approximately 60 minutes. The need for this interview emerged from field observations and aimed to deepen the understanding of issues related to the seasonal hydrological variability of the Solimões and Javari rivers.

d) *Secondary Documents*: Reports from the Civil Defense agency regarding river floods and droughts were analyzed, as well as organizational documents from AMPEC-IPS, such as records of cargo and freight transportation fees. These documents complemented the analysis by contributing to a deeper understanding of the phenomenon under investigation.

The *data collection instruments* were developed and validated based on previous studies on SCM and the *Ripple Effect*, as presented in the Theoretical Framework of this study. The questions explored aspects such as the impacts of river droughts on supply logistics, mitigation strategies, and collaborative practices.

Qualitative data were analyzed using *content analysis*, a technique suitable for achieving "critical unveiling" and applicable to highly diverse discourses (Bardin, 2011). The choice of this approach is justified by the need to interpret the underlying meanings in participants' narratives, going beyond mere thematic categorization. The analytical process followed these steps:

1. *Transcription and Exploratory Reading*: All interviews were fully transcribed and examined through an initial reading to identify recurring themes.

2. *Coding and Categorization*: Based on the theoretical framework, the data were organized into three main categories, which were validated according to the participants' responses.

3. *Definition of Subcategories and Analytical Criteria*: The subcategories were structured to deepen the interpretation of the observed phenomena, as detailed in Table 2.

Table 2

Analytical Framework: Categories, Subcategories, and Criteria.

Categories	Subcategories	Criteria
1. Water Seasonality and Supply Chain Logistics	1.1 River flooding	• Document analysis
	1.2 River recession	
	1.3 Navigability	• Analysis of the responses obtained in the unstructured interview
	1.4 Safety	
	1.5 Enforcement	
	1.6 Control	
2. Logistical Impacts of the Ripple Effect	2.1 Competitiveness	• Analysis of the responses obtained in the unstructured interview; • Analysis of field notes from non-participant observations.
	2.2 Cross-functional coordination	
	2.3 Interorganizational coordination	
3. Policies for Mitigating the Ripple Effect in Supply Chains	3.1 Robustness	
	3.2 Flexibility	
	3.3 Redundance	
	3.4 Proactivity	
	3.5 Reativity	

Source: elaborated by the authors (2024).

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This study adopts an exclusively qualitative approach, as the quantitative data presented (such as logistics costs, river level variations, and freight rate adjustments) were not subjected to statistical inference or quantitative modeling. Instead, they were used solely as complementary evidence to support the qualitative analysis. These data were treated descriptively, with the aid of spreadsheets, ensuring methodological coherence and alignment.

To ensure the validity and reliability of the findings, the study employed data triangulation, combining information obtained from interviews, institutional documents from AMPEC-IPS, and direct observations. Furthermore, preliminary results were reviewed by the participants, allowing for adjustments to minimize ambiguities and interpretive biases. In this way, the research ensures methodological rigor, consistent with its scope and objectives.

PRESENTATION AND DISCUSSION OF RESULTS

Dynamics of Amazon River Low Water Levels and Their Relationship with the Supply Chain

From an economic and commercial perspective, the Solimões Waterway plays a fundamental role as one of the main transportation routes for the flow of goods and cargo in the Amazon region. The Solimões River, the main tributary of the Amazon River, stretches from the western Brazilian border (Colombia and Peru) to the municipality of Manaus (AM), crossing several localities within the state of Amazonas. This waterway has a navigable length of 1,630 kilometers and an average width of 1,210 meters (DNIT, 2021).

Figure 1
Solimões Waterway.

Source: National Department of Transport Infrastructure (2021).

The reliance on the Solimões Waterway renders the supply chain vulnerable to disruptions, as it serves as the primary transportation route for goods and cargo bound for Benjamin Constant. According to Ferreira (2023), 80% of the vessels navigating this route carry frozen products and grains such as soybeans and rice, transporting an average of 488 tons on the outbound journey and merely two tons on the return leg. This asymmetry underscores the waterway's central role in the supply logistics of the Upper Solimões region.

As noted by Garcia (2022), while the fluvial transport mode is essential for connecting suppliers and merchants across the Upper Solimões, it faces considerable challenges during the river's low-water periods. In such instances, cargo destined for Benjamin Constant is redirected to Tabatinga (AM), located 25 kilometers away, requiring the use of small wooden boats, known as canoões, for the final leg of the journey. This adaptive solution reflects local operational flexibility (Zavala-Alcívar et al., 2020; Dolgui et al., 2018), yet it is constrained by high costs and limited capacity, highlighting the urgent need for more robust investments in logistical infrastructure.

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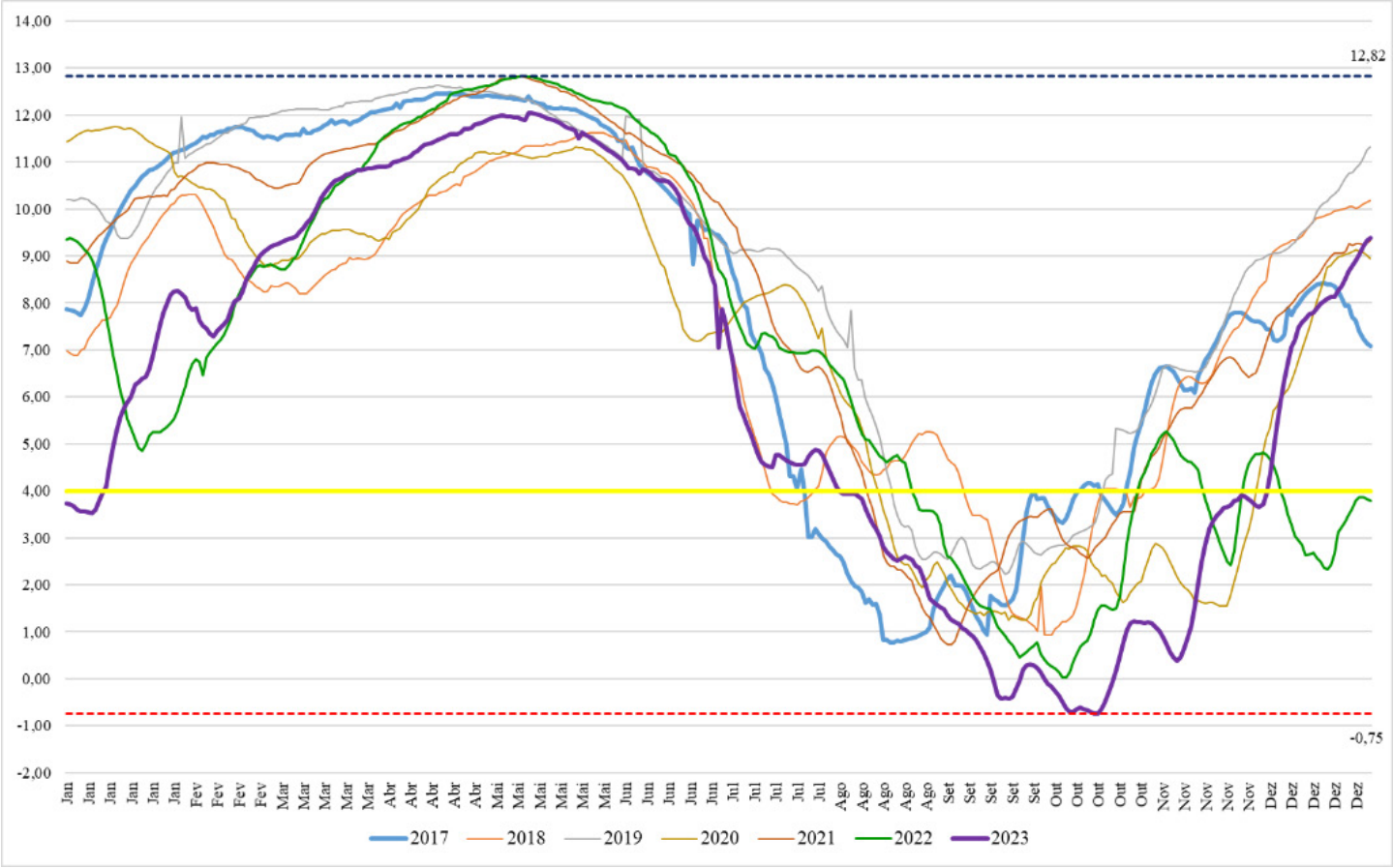
According to the Civil Defense Authority of Benjamin Constant, climate change has led to unprecedented fluctuations in the Solimões River's flow, complicating the forecasting of low-water seasons. Measurements by the Port Authority in Tabatinga indicate an annual intensification of these variations, taking into account the 4.0-centimeter navigability threshold, defined based on local interviews, as illustrated in Graph 1.

Graph 1

Variability in the Hydrological Regime of the Solimões River.



Source: Civil Defense of Benjamin Constant (2023), elaborated by the authors.

The merchants interviewed reported difficulties in anticipating the impact of the low-water season on their inventory levels, due to the unpredictability of the Solimões River's water level, as illustrated in Graph 1. This uncertainty hampers effective inventory replenishment planning and may heighten the vulnerability of the regional supply chain, thereby amplifying the *Ripple Effect* (Yun & Ülkü, 2023; Hsu et al., 2022). Vulnerability to disruptions caused by extreme weather events is among the key factors that increase the potential severity of the *Ripple Effect* (Hsu et al., 2022; Kumar et al., 2023).

The exclusive reliance on the Solimões Waterway—functioning as the sole primary logistical channel—reflects a structural weakness in local supply chains. According to Ivanov (2018), such dependence on a single mode of transportation amplifies the *Ripple Effect*, creating bottlenecks that disrupt the continuity of commercial operations. Furthermore, sole sourcing, as highlighted by Dolgui et al. (2018), is a fundamental driver of heightened disruption impacts on both execution and performance, thereby triggering the *Ripple Effect* within local supply chains. These findings support *Proposition 1* of this study, which posits that river seasonality in the Amazon exacerbates the Ripple Effect by increasing logistical costs and undermining the operational efficiency of local supply chains.

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Analysis of the Ripple Effect Induced by Seasonal River Low Flows

The contents analyzed in this category include: a) *Competitiveness*: relating to customer satisfaction, brand image, reputation, and market share; b) *Interfunctional coordination*: addressing pricing policies, service levels, transportation, lead times, inventories, and downstream disruptions (to customers); c) *Interorganizational coordination*: involving topics such as integration, cooperation, collaboration, and upstream disruptions (to suppliers).

Interviewees were asked *how the low-water periods in the rivers have impacted the availability of goods in their businesses, and which types of goods were most affected*. I1 states that the low-water season does not directly affect the availability of products but does harm the quality of frozen goods due to exposure to sunlight during transportation. I2 highlights that waterborne logistics face difficulties in allowing large vessels to access the port, thus compromising the availability of products. I3 agrees that the low-water season impacts logistics, with frozen goods being the most affected by transportation issues.

It is observed that local disruptions from the *Ripple Effect* have propagated downstream, affecting performance and altering the structural dynamics of the supply chain, leading to performance degradation (Dolgui et al., 2018), and causing significant operational efficiency problems (Li & Zobel, 2020; Llaguno et al., 2021; Korder et al., 2022). The use of *canoões* (small wooden boats) for transportation during the low-water season is a context-specific adaptive solution in the Amazon region and corroborates Garcia's (2022) study. Although limited in efficiency, this practice highlights the operational resilience of local merchants and contributes to expanding discussions on logistical flexibility in extreme scenarios.

Interviewees were asked *if they could share any other specific examples of how the river low-water periods affect their supply chains*. I1 points out that the low-water season complicates the transportation of goods, affecting both product quality and prices to consumers. I2 highlights losses of perishable goods due to delays and issues with exchanges between merchants. I3 emphasizes the increase in transportation costs, which hinder regional transport, negatively impacting business activities and local quality of life. These examples illustrate how the river low-water season undermines interfunctional coordination, directly affecting the flow of goods and the quality of transported products, proving how the *Ripple Effect* can lead to significant operational efficiency losses in vulnerable supply chains (Li & Zobel, 2020; Llaguno et al., 2021; Korder et al., 2022).

Interviewees were asked *how customers have reacted to the price increases during the river low-water periods*. I1 reports that, although some customers complain about the higher prices, most understand the logistical difficulties during the low-water season. I2 highlights that the additional logistical costs make price adjustments inevitable but believes in the need for unity between business owners and consumers to face this period. I3 observes that price increases vary depending on the product, with some cases showing insignificant increases that do not justify passing the costs onto consumers, although more significant adjustments are recognized in specific situations. During the observations conducted, data were collected regarding the adjusted freight rates during low-water periods, which are consolidated in Table 3.

Table 3

Freight Rate Adjustment (%) (BRL) during the River Low-Water Periods. Route: Manaus / Benjamin Constant.

Items	Manaus / Tabatinga		Tabatinga / Benjamin	Adjustment
	Previous Freight (R$)	Adjusted Freight (R$)	Additional Freight (R$)	(%)
Box of chilled goods	0,60	1,00	2,00	400,0
Crate of beverages (600ml)	5,00	10,00	4,00	180,0
Mixed bundle (30kg)	4,00	6,00	5,00	175,0
Box of eggs	5,00	9,00	4,00	160,0
Box of beverages (350ml)	1,00	2,00	0,50	150,0
Box of ceramics	6,00	10,00	5,00	150,0
Package of soft drinks (2L)	2,50	4,00	2,00	140,0
Crate of beverages (1L)	5,00	8,00	4,00	140,0
Assorted boxed goods / Mixed crates	3,00	4,00	3,00	133,3
Water jug (20L) / 20-liter water container	5,00	8,00	3,00	120,0
Animal feed (50kg)	7,00	10,00	5,00	114,3
Sack of cement / Cement bag	8,00	10,00	5,00	87,5
Average Adjustment (%)				**162,5%**

Source: elaborated by the authors (2023).

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The significant increase in freight costs, as shown in Table 1, was highlighted by the interviewees as one of the main challenges faced during the low-water season. Merchants reported that this increase pressures the final prices of products, making supply even more challenging for the local community, illustrating how seasonality amplifies the economic impacts along the chain, thus corroborating the theories of Dolgui et al. (2018).

Interviewees were asked *whether their suppliers allow any flexibility in the agreements during the river low-water periods, and how this relationship functions during this time*. The interviewees emphasized the lack of flexibility in supplier agreements during the low-water season, highlighting a significant gap in interorganizational collaboration. The absence of collaborative practices limits the supply chains' ability to become resilient and mitigate disruptions (Yun & Ulku, 2023; Shekarian & Parast, 2020), thereby intensifying the *Ripple Effect* in the region.

Interviewees were asked *if they notice any reduction in consumer demand during the river low-water periods, and which type of goods is most affected*. I1 reports that their sales do not experience significant reductions during the low-water season, as the most sold products, such as bottled water and beverages, have consistent demand in the Amazonian heat. I2 also observes a stable demand for essential foods, although price increases may cause slight declines. I3 points to a slight reduction in sales, especially for perishable products such as breaded foods and hamburgers, due to transportation difficulties that affect quality. These responses suggest that the river low-water periods affect sales of different types of products in varied ways, corroborating the idea that resilience does not always improve at the same pace as sustainability, making it a complex and non-linear relationship (Freeman, 2023; Bezares et al., 2021).

Interviewees were asked *about their perception of how the river low-water periods affect client companies and other partners*. I1 states that the low-water season impacts all merchants in the region, regardless of sector, and notes that Atalaia do Norte also suffers from these impacts. I2 highlights the complexity of the supply chain, mentioning issues such as loss of goods and delays, as well as raising concerns about the lack of diesel fuel, essential for the local thermoelectric plant. I3 confirms that the low-water period affects all sectors, from small markets to large merchants, including the supply of construction materials and cooking gas, and observes that the situation worsens each year.

The interview responses indicate that the low-water periods of the Amazon rivers affect not only their own businesses but also other businesses, clients, and partners in their respective communities. In other words, its effect is perceptible within the broader organizational macroenvironment. *Ripple Effect* disruptions spread among businesses and have impacted the entire network (Li & Zobel, 2020; Llaguno et al., 2021; Korder et al., 2022). Moreover, the impacts of the low-water season extend beyond the commercial aspect, affecting the organizational macroenvironment. The increase in transportation costs for people and the difficulty in supplying diesel fuel to the local thermoelectric plant reflect how disruptions spread across different sectors, amplifying the *Ripple Effect* in a vulnerable regional context.

The results confirm *Proposition 1*, demonstrating how the seasonality of the Amazon rivers intensifies the *Ripple Effect* in local supply chains, increasing logistical costs and compromising operational efficiency. The difficulty in the flow of goods, increases in logistical costs, and adaptive solutions such as the use of *canoões* illustrate this dynamic in the Amazonian context. Furthermore, the lack of flexibility in agreements between merchants and suppliers reveals one of the most critical challenges of interorganizational coordination. The absence of collaborative practices limits the ability to respond to disruptions, exacerbating the impacts of seasonality on logistical performance, which confirms *Proposition 3* of this study.

Mitigation Policies of the Ripple Effect by Merchants

The contents analyzed in this analytical category include: a) *Robustness*: refers to the supply chain's ability to withstand shocks and disturbances; b) *Flexibility*: relates to the ability to quickly adapt to changes in market conditions, customer

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demand, or unforeseen disruptions; c) *Redundancy*: involves creating backups or alternatives for critical components of the supply chain; d) *Proactivity*: encompasses the ability to anticipate potential issues and act before they occur; e) *Reactivity*: deals with the ability to respond effectively to unexpected events that affect the supply chain.

Interviewees were asked *what strategies they implement to minimize the impact of the river low-water periods on their supply chains*. I1 highlights the importance of maintaining stocks of bottled water due to its essential nature during the low-water period, adopting a proactive approach for other products as well. I2 faces the logistical challenge of large vessels being unable to dock at the port, opting to outsource smaller vessels, although this carries the risk of goods loss. I3, with financial and space limitations, is unable to implement proactive strategies and adopts a reactive approach, adapting as conditions change.

It is observed that the strategies adopted by companies vary from *redundancy*, such as stocking essential products, to *flexibility*, such as outsourcing smaller vessels, and reactivity, where companies respond to conditions as they arise, due to financial limitations. These strategies align with the literature (Zavala-Alcívar et al., 2020; Dolgui et al., 2018) and demonstrate the complexity of SCM in a region affected by the low-water season, and the constant need to adapt to the imposed conditions, particularly due to climate change (Yun & Ülkü, 2023). However, reactivity to disruptions indicates the absence of contingency plans, which is considered one of the primary reasons for the increased *Ripple Effect* (Dolgui et al., 2018).

Redundancy strategies, such as stocking essential products, and *flexibility strategies*, such as outsourcing smaller vessels, partially confirm *Proposition 2* of this study, highlighting how integrated practices mitigate the impacts of the *Ripple Effect* in vulnerable regions, despite financial and structural limitations.

Interviewees were asked *whether they would consider using an alternative means of transportation to the waterway modal during the low-water periods*. I1 suggests building a road to Guanabara to reduce the impacts of the low-water season, but acknowledges the complexity of the project in the short term and the lack of viable alternatives. I2 agrees that there is no other accessible transportation option. I3 emphasizes the scarcity of alternatives, citing the high cost of air transport and the lack of airport infrastructure. He mentions river dredging as a solution but highlights the dependence on government actions.

The interviewees agree that transportation alternatives during the low-water season are severely limited, highlighting the critical dependence on the waterway modal (Nogueira & Oliveira, 2019). This exclusive dependence not only amplifies the *Ripple Effect* but also exposes the structural fragility of regional supply chains, confirming the discussions of Dolgui et al. (2018) and Ivanov (2018) regarding the risks of single-source supply.

The interviewees were asked *whether they made adjustments to their inventory policies during the low-water periods*. I1 adopts a proactive approach, purchasing goods such as bottled water in advance when resources are available, and negotiating prices with carriers to minimize costs. I2 considers early storage useful but points out limitations in capacity and suppliers' lead times. I3, due to financial and space restrictions, cannot implement proactive strategies, describing the situation as "very difficult."

While some interviewees adopt proactive measures, others face financial and structural challenges that limit their ability to make significant adjustments to their inventory policies during the low-water season. This reflects the diversity of conditions and resources among businesses in the region affected by the low-water season. The reduction in downstream storage facilities in the supply chain (Ivanov, 2018) and low safety stock levels (Dolgui et al., 2018) amplify the *Ripple Effect*. Furthermore, the presence of redundancies such as stocks and reserve capacities are cited as proactive strategies for mitigating the *Ripple Effect* (Dolgui et al., 2018). While Dolgui et al. (2018) suggest safety stocks as essential mitigators, this study reveals that local merchants face financial and structural barriers that hinder this practice, emphasizing the need for collaborative alternatives (Shekarian & Parast, 2020). These strategies applied by the merchants reflect varying levels

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of resilience, ranging from robustness, flexibility, and redundancy, as suggested by Zavala-Alcívar et al. (2020), confirming *Proposition 2* of this study.

The interviewees were asked *about interorganizational integration, collaboration, and cooperation during the low-water periods*. I1 notes improvements in collaboration between business owners, the Civil Defense, municipal governments, and the Navy, highlighting frequent meetings of the Merchant Association to seek solutions. I2 praises the work of the Association but points out the need for more political support and the involvement of competent authorities. I3 mentions limited partnerships between business owners and criticizes the lack of government collaboration, leaving merchants to "fend for themselves."

These responses reflect the variety of collaboration initiatives in the region, with some cases of cooperation between business owners and other actors, but also highlight the need for greater involvement of authorities and government agencies to effectively address the challenges posed by the low-water season. Collaboration between businesses helps manage disruptions and improves overall supply chain resilience (Yun & Ulku, 2023; Shekarian & Parast, 2020), as well as providing greater sustainability for businesses (Yun & Ulku, 2023). The need for the involvement of authorities and government agencies is particularly important, as local policies and regulations must support and encourage resilient practices to climate change in supply chains (Yun & Ulku, 2023), confirming the need to strengthen interorganizational coordination to promote resilience in the Amazonian context, reinforcing *Proposition 3* of this study.

CONCLUSIONS

This study revealed that the seasonality of the Amazon rivers, exacerbated by climate change, intensifies the *Ripple Effect* in local supply chains, causing significant impacts such as increased logistics costs, compromised operational efficiency, and limited transportation alternatives. The mitigation strategies adopted by merchants, such as flexibility, redundancy, and robustness, proved to be effective in partially mitigating these impacts. The adaptive strategies adopted by merchants, such as the use of smaller vessels (*canoões*), stock formation, and targeted negotiations, highlight local resilience but also expose structural and financial barriers that limit the effectiveness of these actions.

The results emphasize the importance of interdisciplinary initiatives to mitigate the impacts of seasonality. Collaborative actions involving merchants, local governments, and regulatory bodies are essential to promote resilient and sustainable practices. This includes strengthening interorganizational cooperation, improving logistics infrastructure, and developing public policies that encourage modal diversification and the creation of safety stocks. The study reinforces that facing climate and logistical challenges in vulnerable contexts, such as the Amazonian region, requires an integrated and innovative approach.

FINAL CONSIDERATIONS

Practical Implications

The findings of this study have direct practical implications for merchants, local authorities, and the population in the region. Strengthening logistics infrastructure through modal diversification should be a priority, with investments in roadways, air transportation, and river dredging. Furthermore, public policies that encourage the formation of safety stocks and the adoption of contingency plans are crucial to mitigate the impacts of disruptions in the supply chain.

The application of emerging technologies can be explored to optimize logistical planning and reduce the vulnerabilities of local supply chains. These improvements not only increase operational efficiency but also generate positive impacts on the population's quality of life by ensuring greater availability and accessibility of essential products, reducing costs, and strengthening the region's socioeconomic development.

Theoretical Implications

This study contributes to the literature on SCM in vulnerable regions by exploring the *Ripple Effect* in the Amazonian context. The findings expand theories such as those of Dolgui et al. (2018) and Ivanov (2018) by highlighting how

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dependence on a single logistical mode amplifies disruptions and how structural barriers limit the implementation of resilient practices. The research also advances the discussion on how interorganizational collaboration enhances the overall resilience of the supply chain, as suggested by the studies of Yun & Ulku (2023) and Shekarian & Parast (2020), pointing out its gaps and potential in scenarios of climate vulnerability.

Limitations of the Study

One of the main limitations of this study was the small sample size, a reflection of the logistical challenges and the specific context of the Amazon region. Additionally, the predominantly qualitative approach limits the possibility of statistical generalizations. However, the inclusion of quantitative data helped contextualize the findings, providing additional support to the analysis and strengthening the understanding of the observed impacts. Another relevant limitation concerns the absence of previous studies analyzing the *Ripple Effect* in isolated markets, such as the Amazon, which restricted direct comparison of the findings with prior research. These factors highlight the need for complementary investigations that broaden the empirical foundation on the topic.

Suggestions for Future Research

The suggestions for future research aim to expand the understanding of Supply Chain Management in vulnerable contexts, such as the Amazon, and offer pathways to mitigate the impacts of the *Ripple Effect*. In this regard, the following research avenues are proposed:

1. *Expanded Quantitative Approach*: Develop studies that allow the measurement of the Ripple Effect impacts across different sectors of the Amazonian economy, enabling a more detailed analysis of the effects of logistical disruptions.

2. *Modal Diversification*: Investigate the economic, operational, and environmental feasibility of logistical alternatives, such as the construction of highways or the expansion of air transport in the region.

3. *Use of Technology*: Study the impact of emerging technologies, such as blockchain, IoT, additive manufacturing, artificial intelligence, drones, satellite navigation systems, among others, in mitigating the Ripple Effect.

4. *Comparative Studies*: Conduct analyses in other regions of the Amazon or in countries facing similar logistical challenges, aiming to identify replicable practices and solutions.

5. *Relationship Between Resilient Logistics and Sustainable Development*: Explore how strategies to mitigate the Ripple Effect can contribute to sustainable socio-economic development in isolated markets, considering aspects such as quality of life, job creation, and accessibility to essential goods.

6. *Broader Perspectives*: Include suppliers, transporters, and consumers in future studies to provide a more comprehensive view of disruptions and strategies within regional supply chains.

REFERENCES

Appolinário, F. (2011). Dicionário de Metodologia Científica: um guia para a produção do conhecimento científico. 2a ed. São Paulo: Atlas.

Bardin, L. (2011). Análise de conteúdo. Edições 70, 2011, 229 p.

Bašić, M., Kovše, Š., Opačić, A., Pećarević, M., & Obrecht, M. (2024). Supply chain management mitigation to climate change in three selected industrial sectors. Logistics, Supply Chain, Sustainability and Global Challenges, 0. https://doi.org/10.2478/jlst-2023-0007.

Bezares, N., Fretes, G., & Martinez, E. (2021). The Role of Food and Beverage Companies in Transforming Food Systems: Building Resilience at Multiple Scales. Current Developments in Nutrition, 5(9). https://doi.org/10.1093/cdn/nzab110.

Chopra, S., & Meindl, P. (2013). Supply chain management. Strategy, planning & operation.

Birkie, S., & Trucco, P. (2020). Do not expect others do what you should! Supply chain complexity and mitigation of the ripple effect of disruptions. International Journal of Logistics Management. https://doi.org/10.1108/ijlm-10-2018-0273.

DOI: https://doi.org/10.14210/alcance.v32n1(jan/abr).p37-53

Cahyono, Y., Purwoko, D., Koho, I., Setiani, A., Supendi, S., Setyoko, P., Sosiady, M., & Wijoyo, H. (2023). The role of supply chain management practices on competitive advantage and performance of halal agroindustry SMEs. Uncertain Supply Chain Management. https://doi.org/10.5267/j.uscm.2022.10.012.

Chopra, S., & Meindl, P. (2013). Supply chain management. Strategy, planning & operation. Gabler.

Departamento Nacional de Infraestrutura de Transportes - DNIT (2021). Hidrovia do Solimões. Disponível em: https://www.gov.br/dnit/pt-br/assuntos/aquaviario/old/hidrovia-do-solimoes.

Dolgui, A., & Ivanov, D. (2021). Ripple Effect and supply chain disruption management: new trends and research directions. International Journal of Production Research, 59(1), 102-109.

Dolgui, A., Ivanov, D., & Sokolov, B. (2018). Ripple effect in the supply chain: an analysis and recent literature. International journal of production research, 56(1-2), 414-430.

Ferreira, I. D. S. (2023). Logística de transporte no Alto Solimões: um estudo sobre os desafios enfrentados pelas embarcações para o transporte de cargas e passageiros durante o período de vazante dos rios (Trabalho de Conclusão de Curso). Universidade Federal do Amazonas, Benjamin Constant, Amazonas.

Freeman, M. (2023). The Interplay Between Supply Chain Resilience and Climate Change. Rangahau Aranga: AUT Graduate Review. https://doi.org/10.24135/rangahau-aranga.v2i3.188

Garcia, A. A. (2022). Logística de suprimentos: um estudo de caso sobre controle de abastecimento de mercadorias da empresa VS Garcia (Trabalho de Conclusão de Curso). Universidade Federal do Amazonas, Benjamin Constant, Amazonas.

Gil, A. C. (2002). Como elaborar projetos de pesquisa. Editora Atlas SA.

Hsu, C., Zeng, J., Chang, A., & Cai, S. (2022). Deploying Industry 4.0 Enablers to Strengthen Supply Chain Resilience to Mitigate Ripple Effects: An Empirical Study of Top Relay Manufacturer in China. IEEE Access, 10, 114829-114855. https://doi.org/10.1109/ACCESS.2022.3215620.

Hugos, M. H. (2018). Essentials of supply chain management. John Wiley & Sons.

Hwihanus, H., Wijaya, O., & Nartasari, D. (2022). The role of supply chain management on Indonesian small and medium enterprise competitiveness and performance. Uncertain Supply Chain Management, 10(1), 109-116. https://doi.org/10.5267/j.uscm.2021.10.005.

Ivanov, D. (2018). Revealing interfaces of supply chain resilience and sustainability: a simulation study. International Journal of Production Research, 56(10), 3507-3523.

Kara, M., Ghadge, A., & Bititci, U. (2020). Modelling the impact of climate change risk on supply chain performance. International Journal of Production Research, 59, 7317 - 7335. https://doi.org/10.2139/ssrn.3652664.

Korder, B., Maheut, J., & Konle, M. (2022). Ripple effect in supply chains: a systematic literature review protocol. Proceedings - 4th International Conference Business Meets Technology 2022. https://doi.org/10.4995/bmt2022.2022.15553.

Kumar, M., Raut, R., Gunasekaran, A., Venkateshwarlu, M., & Choubey, V. (2023). Developing Supply Chain Capabilities Through Digitalization and Viability for Controlling the Ripple Effect. IEEE Transactions on Engineering Management. https://doi.org/10.1109/tem.2022.3233860.

Li, Y., & Zobel, C. (2020). Exploring supply chain network resilience in the presence of the ripple effect. International Journal of Production Economics, 107693. https://doi.org/10.1016/j.ijpe.2020.107693.

Llaguno, A., Mula, J., & Campuzano, F. (2021). State of the art, conceptual framework and simulation analysis of the ripple effect on supply chains. International Journal of Production Research, 60, 2044-2066. https://doi.org/10.1080/00207543.2021.1877842.

Marconi, M. A. & Lakatos, E. M. (2018). Técnicas de pesquisa. Atlas.

Nogueira, J. R., & Oliveira, K. B. (2019). Estudo de caso: impacto dos custos logísticos em agroindústria de polpas de frutas no município de Benjamin Constant-Amazonas: impact of logistic costs on fruit pulp agroindustry in the municipality of Benjamin Constant-Amazonas. UFAM Business Review-UFAMBR, 1(2), 42-66.

DOI: https://doi.org/10.14210/alcance.v32n1(jan/abr).p37-53

Rodrigues, M., Santos, A., Lima, H., Nogueira, W., & De Lucena Júnior, V. (2025). Tracking Boats on Amazon Rivers – A Case Study with the LoRa/LoRaWAN. Sensors (Basel, Switzerland), 25. https://doi.org/10.3390/s25020496.

Severino, A. J. (2007). Metodologia do Trabalho Científico. Cortez.

Shekarian, M., & Parast, M. (2020). An Integrative approach to supply chain disruption risk and resilience management: a literature review. International Journal of Logistics Research and Applications, 24, 427-455. https://doi.org/10.1080/13675567.2020.1763935.

Siahaan, T., Nazaruddin, S. I., & Sadalia, I. (2020). The effect of supply chain management on competitive advantage and operation organization performance at PT PLN (Persero). International Journal of Research and Review, 7(4), 80-87.

Stake, R. E. (2000). Case studies. In: Denzin, N. K. (Edit.); Lincoln, Y. S. (Edit.), Handbook of qualitative research (pp. 435-454). Thousand Oaks.

Tadaiesky, D., Neto, J., Melo, A., Anholon, R., De Castro Coutinho, E., & Martins, V. (2022). Challenges to Promoting Resilience in Supply Chains Observed during the COVID-19 Pandemic: An Exploratory Study of the Amazon Region Using the TOPSIS Technique. Logistics. https://doi.org/10.3390/logistics6040078.

Wieland, A. (2021). Dancing the Supply Chain: Toward Transformative Supply Chain Management. The Journal of Supply Chain Management, 1(57), 58-73. https://doi.org/10.1111/jscm.12248.

Wunderling, N., Staal, A., Sakschewski, B., Hirota, M., Tuinenburg, O., Donges, J., Barbosa, H., & Winkelmann, R. (2022). Recurrent droughts increase risk of cascading tipping events by outpacing adaptive capacities in the Amazon rainforest. Proceedings of the National Academy of Sciences of the United States of America, 119. https://doi.org/10.1073/pnas.2120777119.

Zhu, X., & Wu, Y. (2022). How Does Supply Chain Resilience Affect Supply Chain Performance? The Mediating Effect of Sustainability. Sustainability. https://doi.org/10.3390/su142114626.

Yun, N. Y., & Ülkü, M. A. (2023). Sustainable Supply Chain Risk Management in a Climate-Changed World: Review of Extant Literature, Trend Analysis, and Guiding Framework for Future Research. Sustainability, 15(17), 13199.

Zavala-Alcívar, A., Verdecho, M. J., & Alfaro-Saiz, J. J. (2020). A conceptual framework to manage resilience and increase sustainability in the supply chain. Sustainability, 12(16), 6300.