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Orchestrating Collective Action for Grand Challenges: A Multi-Level Study of Relationships, Architectures, and Networks

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PART I: Conceptual and Theoretical Background

1. Introduction

1.1. Background

Literature on grand challenges underscores the critical importance of collaboration among multiple independent actors, whose collective efforts are essential to tackling societal problems beyond the scope of any single organization (Ferraro et al., 2015; Howard-Grenville & Spengler, 2022). These global issues are defined as "*formulations of global problems that can be plausibly addressed through coordinated and collaborative effort"* (George et al., 2016).

A renewed wave of interest in research on grand challenges has attracted scholars from diverse disciplines seeking to advance solutions to pressing societal issues, such as poverty reduction, resource accessibility, climate change, and environmental safeguarding (Ferraro et al., 2015; Gehman et al., 2022; George et al., 2016; Gümüsay et al., 2022b). These challenges are inherently complex and lack clearly defined solutions. Consequently, they resist conventional approaches and instead require innovative approaches, bold ideas, and cross-sectoral collaboration by independent actors across different fields and institutions (Churchman, 1967; Ferraro et al., 2015; Gehman et al., 2022). This additional complexity demands that organizations navigate across interdependent and systemic issues that transcend organizational and sectoral boundaries (Brammer et al., 2019; Ferraro et al., 2015; Gümüsay et al., 2022b, 2022a). Organizations are thus required to design and sustain collaborative networks, in which multiple actors coordinate efforts and mobilize resources for collective goals (Gehman et al., 2022; Rouyre et al., 2024). In this context, policymakers, corporations, non-governmental organizations, and associations represent collective actors whose interactions within inter-organizational settings can drive progress on societal challenges (Angeli et al., 2022; Drori et al., 2025; George, Fewer, et al., 2024a; Leixnering et al., 2025). Therefore, advancing progress for grand challenges largely depends on the orchestration of actors, activities, and resources at multiple levels toward the creation of collective value (George,

Fewer, et al., 2024a; Gulati, Wohlgezogen, et al., 2012a; Leixnering et al., 2025; Reypens et al., 2021). Yet, despite growing attention to these dynamics, our understanding of how coordination and collaboration emerge and evolve within networks and across levels in these contexts remains limited.

Understanding how coordination and collaboration emerge in these contexts is crucial and requires integrating insights from theories of coordination, inter-organizational collaboration, and network governance (Couture et al., 2023; George, Fewer, et al., 2024a; Olsen et al., 2016). This is particularly important as grand challenges require collective action at multiple levels: coordinated behaviors by collaborating actors to achieve a shared objective (George, Fewer, et al., 2024a; Olson, 1965; Ostrom, 1998). Managing collective action at multiple levels requires navigating extensive interaction spaces, where principles and practices within diverse domains are both influenced by, and exert influence on, different levels (Bridoux & Stoelhorst, 2022a; Drori et al., 2025; Gupta & Nilsson, 2017). These interactions often create space for collaboration, resource exchange, and mutual influence (George, Fewer, et al., 2024b; Weber & Khademian, 2008). Organizations must develop common interests (Lee et al., 2017), align perceived efficacy (Lee et al., 2017), and mobilize resources and expertise (Taylor & Singleton, 1993). In such contexts, orchestrators are lead organizations capable of facilitating coordination and sustaining collaboration among actors. They play a key role in bridging actors, aligning activities, and establishing governance rules (Dhanaraj & Parkhe, 2006; Roehrich et al., 2023).

Addressing grand challenges requires the formation of networks of actors capable of collaborating beyond the boundaries and objectives of any single organization. These networks operate across multiple levels and involve diverse forms of interaction, bringing together actors who are simultaneously interdependent and autonomous, yet committed to tackling urgent societal problems. In such contexts, orchestration becomes a critical mechanism through which collective action and coordinated responses to complex societal problems can emerge and be sustained.

1.2. Aim and rationale

Building on the literature on grand challenges, this research investigates how orchestration unfolds within collaborative networks across three analytical levels: *interpersonal, organizational, and network* levels. Specifically, it seeks to understand how coordination emerges from the core level and scales to enable collective action across broader network systems. Adopting a multi-level perspective allows us to capture how individual actions align, aggregate, and translate into collective action that generates tangible societal outcomes. While previous studies have emphasized the need for coordination and collaboration in addressing grand challenges, they often overlook the distinct mechanisms and interdependencies across levels through which such coordination develops and produces impact. To address this gap, this work aims to advance an integrative framework grounded in theories of collaboration, coordination, and network orchestration. By analyzing interpersonal, organizational, and network dynamics, we unpack how coordination emerges and how orchestration practices enable the alignment of actors and support collective action from the ground up in the pursuit of shared societal goals.

The following three research questions guide this study and serve as the analytical focus for each paper. Together, they explore coordination, orchestration, and collective action across the three distinct yet interrelated levels of analysis. Each question is designed to uncover the mechanisms that enable coordination within and across these levels, thereby contributing to a deeper understanding of how orchestration supports collaborative response to grand challenges. The research questions are:

- *How do interpersonal interactions enable knowledge sharing within the dynamic work environments of grand challenges? How does learning unfold in such contexts?*

- *How do organizations govern and coordinate the data value chain in grand challenge contexts characterized by heterogeneous, dispersed, and boundary-spanning data?*

- *How do lead organizations orchestrate inter-organizational networks to overcome coordination challenges and sustain collective action in response to grand challenges?*

1.3. Structure of the work

The work comprises a collection of three papers exploring how organizations mobilize resources and coordinate efforts in addressing pressing societal challenges, labelled *grand challenges*. The papers are three qualitative studies based on rich in-depth data consisting of multiple typologies, including ethnographic observations, interviews, and documents. They are structured as follows:

- The first paper explores coordination at the interpersonal level, emphasizing micro-level interactions and coordination that support knowledge sharing and foster learning forms within distributed collaborative activities.
- The second paper examines the organizational level, analyzing how a lead organization manages internal structures composed of the technical infrastructure, the organizational dimension, and the physical dimension to coordinate and align internal and external actors.
- The third paper addresses the network level, focusing on how orchestration practices shape and sustain multi-actor networks over time.

The first paper aims to illustrate how diverse forms of interpersonal interactions support tacit and explicit knowledge sharing. It explores how these interactions lead to diverse types of learning – reflexive, experimental, contextual, and vicarious learning within grand challenges settings that are typically characterized by non-linear problems, complex operations, knowledge-intensive tasks, and distributed experimentations conducted by a plurality of actors. This work contributes to the knowledge-sharing literature by demonstrating how these processes unfold across a range of activities, from ordinary tasks to unpredictable situations, and through various forms of interactions, including face-to-face and digital exchange, within such dynamic environments. The National Park of Abruzzo, Lazio and Molise (PNALM) represents our empirical context where members address the environmental safeguarding challenge in a context characterized by rapid and unpredictable events, high demands on human resources, and quick decision-making. By analyzing dispersed team operations and coordinated activities across a challenging and vast territory, we demonstrate the paramount role of interpersonal interactions, encompassing standard, situational, and critical activities, mediated through both face-to-face and digital exchanges, in fostering different forms of learning. Empirical evidence further highlights how these forms of learning, including

experimental, reflective, contextual, and vicarious learning, contribute differently to the development of explicit and tacit knowledge. In eliciting the crucial role of interpersonal interactions within organizations facing grand challenges, this work reveals how these interactions serve as basic foundations for knowledge creation and organizational learning in such complex and uncertain environments.

The second paper is a qualitative exploration of technological aspects and their role in grand challenges contexts, where data-driven technologies represent both an advantage and a source of additional complexity. In these contexts, data management is particularly challenging, as organizations are involved in distributed activities across extensive territories, multistakeholder collaborations, heterogeneous tools, and innovative approaches. In this paper, we extend the empirical context by including close PNALM stakeholders. Here, data-based collaborations further increase the complexity of the Data Value Chain (DVC) configuration, which encompasses the collection, storage, and extraction of actionable value from data. We aim to illustrate how organizations configure DVC by orchestrating actors, resources, operations, and combined data flows originating from digital and analog technologies throughout extensive territories. Contributions of this work extend the linear vision of the DVC in favor of a more multifaceted model, highlighting the importance of adaptive management and integration of three interconnected dimensions: physical, technical, and organizational, to derive meaningful value from data in grand challenges contexts. The results underscore the importance of fostering collaboration among internal units and external partners to amplify technical capabilities and resources along the DVC. Overall, this study demonstrates how an integrated, multidimensional, and collaborative approach to the DVC becomes essential for enabling effective data-driven solutions in complex and uncertain grand challenge environments.

The third paper broadens the analytical lens and adopts an inter-organizational perspective, investigating how networks of organizations orchestrate and mobilize collective action to tackle grand challenges. The aim of this paper is to explore the role of lead orchestrators in orchestrating network collaborations in conditions of limited authority, trust, and resources, often typical of grand challenges initiatives, and identify which mechanisms enable collective action. We develop a framework that illustrates how network orchestration unfolds through three key strategies: setting up network leadership,

building network legitimacy, and scaffolding network governance. The results suggest that orchestrators must leverage collective leadership and a shared sense of belonging while supporting the development of bottom-up, participatory governance capabilities across the network in grand challenges initiatives. This paper demonstrates the crucial importance of these strategies, where relying solely on authority or resources may not be sufficient. These strategies can be employed to strengthen the capacity of inter-organizational networks to meet increasingly complex societal needs where conventional coordination approaches fall short.

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2. Theoretical Background

Grand challenges are ambitious, complex problems that lack clearly defined solutions, are characterized by evolving requirements, and involve the participation of multiple actors across different fields and institutions (Churchman, 1967; Ferraro et al., 2015; Gehman et al., 2022). Addressing these societal problems requires large-scale initiatives and collaborative efforts, which often give rise to additional organizational challenges that must be effectively managed (Brammer et al., 2019; Ferraro et al., 2015; Gümüsay et al., 2022b, 2022). Such collaborative efforts often result in specific initiatives undertaken by multiple actors to achieve a common goal (Gehman et al., 2022; Rouyre et al., 2024). Consequently, the debate on grand challenges primarily emphasizes collaboration and cooperation rather than individual initiatives. In this context, policymakers, corporations, non-governmental organizations, and associations are examples of collective actors whose interactions within inter-organizational settings can advance progress on societal challenges (Angeli et al., 2022; Drori et al., 2025; George, Fewer, et al., 2024a; Leixnering et al., 2025). However, within grand challenges, coordination mechanisms present additional complexity, given the lack of central authority and the fluidity of participants' roles and objectives.

2.1. Coordination theories

Theories of collaboration provide relevant insights into how inter-organizational relationships and interdependencies are managed within multi-actor settings. These theories are grounded in the main assumption that collaboration among organizations constitutes a strategic behavior. This enables actors to pursue common objectives, respond to increasingly complex environments while maintaining autonomy and interdependence (Gulati et al., 2012). Collaboration theories can serve as a lens to examine the processes through which actors, "*who see different aspects of a problem"*, constructively seek solutions beyond their individual perspectives and capabilities (Gulati, Wohlgezogen, et al., 2012c; Wood & Gray, 1991). Inter-organizational collaboration refers to efforts aimed at addressing problems that cannot be resolved by unilateral organizational action.

Accordingly, these theories provide a foundation to explore antecedents, motivations, incentives, and outcomes of organizations participating in multi-actor arrangements.

Collaboration theories are often discussed through two major interrelated perspectives: cooperation and coordination (Gulati et al., 2012). Cooperation refers to "*joint pursue of agreed goals"*, grounded in the alignment of tasks, shared resources, incentives, and interests. Coordination, in contrast, involves the *"deliberate and orderly alignment of joint actions"* to achieve the partner's shared objectives (Gulati, Wohlgezogen, et al., 2012a; Malone & Crowston, 1990). It encompasses the alignment of activities, resources, and knowledge across organizational boundaries and relies on processes of information-sharing, decision-making, and feedback mechanisms in order to integrate partners' efforts and resources effectively (Gray et al., 2000).

Coordination has long represented a central concern in management literature, tracing its roots to classical organizational theory. Foundational contributions by Herbert Simon, James G. March, and Thomas W. Malone reflected on how actors can collaborate harmoniously and the challenges that arise from these interactions. March & Simon (1958) emphasized the importance of managing interdependencies among organizational tasks to reduce uncertainty and enhance collective performance. These interdependencies, combined with incomplete information (reflecting bounded rationality), conflicting objectives, and organizational rigidities, may lead to coordination challenges (Simon, 1991). Such challenges may be addressed by identifying and characterizing the coordination processes involved. These include the allocation of shared resources, the management of relationships among actors through participatory design, and the decomposition of tasks resulting from the selection of shared goals (Malone & Crowston, 1990, 1994).

Theories of coordination have evolved significantly over the past decades, moving from classical organizational perspectives focused on internal task interdependencies and hierarchical supervision to recent literature that addresses the complexities of inter-organizational networks. While traditional coordination theories emphasize mechanisms such as standardization, mutual adjustment, and hierarchical supervision, recent developments reflect the increasing complexity of inter-organizational and networked contexts. For instance, coordination has been studied within the literature on

multistakeholder initiatives (Gray & Purdy, 2018), cross-sectoral partnerships (Stadtler et al., 2024), inter-organizational projects (Roehrich et al., 2024), and collective action settings (Drori et al., 2025; Rosca et al., 2022). Contemporary literature, particularly in the context of collaborative networks, emphasizes new challenges such as aligning actions among network participants, establishing collaborative governance mechanisms, balancing powers and institutional constraints, and scaling impact across contexts and levels.

Effective coordination depends on both relational processes, including trust, communication, and shared understanding, as well as structural features, such as governance arrangements and network configurations that enable distributed actors to align their actions over time. Consequently, coordination theories represent the fundamental conceptual building blocks for studying the orchestration of collective action in the context of grand challenges.

2.2. Collective action

Collective action theories are adopted to pose central relevance on how coordinated behaviors by multiple actors can achieve a shared objective and avoid coordination failures (George, Fewer, et al., 2024a; Olson, 1965; Ostrom, 1998). With *The Logic of Collective Action,* published by Mancur Olson (Olson, 1965), the author challenges previous assumptions on collaboration, arguing that groups would tend to form and take collective action not only whenever members jointly benefited, but only under specific conditions that overcome individual self-interest. These conditions occur when groups are sufficiently small to make individual contributions visible, or when mechanisms of coercion, selective incentives, or institutional arrangements are established to align individual and collective interests. According to the author, the primary function of organizations is to advance the common interests of individuals. When this common interest exists, any individual, unorganized action would fail. Conversely, despite the existence of diverging individual interests from the common interest, inter-organizational systems may take advantage of collective action in terms of transactional, strategic, and information benefits.

More recent developments have posed several challenges to the common assumptions on collective action. Ostrom (2000) emphasized that collective action situations can often be successfully resolved by individuals and groups capable of self-organizing, rather than being limited by solely self-interest. The author challenges previous views on collective action by arguing that coordination emerges from locally developed rules, clear boundaries, trust, and continuous interactions. Building on these insights, recent contributions have extended collective action theories to inter-organizational and network contexts, focusing on mechanisms such as aligning perceived efficacy (Lee et al., 2017), fostering common interests (Lee et al., 2017), establishing authority (Davis, 2016), and mobilizing resources and expertise (Taylor & Singleton, 1993). In this perspective, collective action is increasingly adopted to examine multi-level phenomena, occurring at the micro, meso, and macro levels, particularly in collaborative inter-organizational networks. Such approaches are critical for examining large-scale collaborative initiatives, due to their collective, multivocal, and experimental nature (Drori et al., 2025; Ferraro et al., 2015).

Drawing upon the basic principles, collective action theories have been adopted to explain how individuals and groups cooperate to achieve shared goals, especially when individuals' contributions are small. These theories inspired contributions across various disciplines, including economics, political science, sociology, and psychology (Olson, 1989) to explain phenomena inherent to public goods, group formation, large-scale community, and social movements. Organizational scholars offered theoretical insights into the problems of how to organize for collective action and paid detailed attention to how research contexts shape collective responses. These approaches are important as they offer contextually relevant and empirically grounded explanations of patterns and mechanisms that facilitate or hinder collective action.

Achieving collective action requires navigating individual and collective interests across diverse domains, including organizational welfare, the provision of public goods, and pressing global issues such as environmental change. Recent studies in collective action research reveal a shift from laboratory-based studies toward more grounded and contextualized investigations that explore motivational, strategic, and structural motivations that shape actors' participation in collective efforts. In this evolving perspective, collective action theories have become particularly valuable as a lens to

examine the mechanisms that enable collaborative efforts, such as knowledge and information sharing, trust and consensus building, resource mobilization, and the development of shared rules. These mechanisms support coordinated behaviors among actors operating in contexts such as those addressing grand societal challenges.

2.3. Network orchestration

As organizations operate in increasingly complex environments, they are progressively shifting from relying on internal resources and capabilities to count more on external networks. In this context, orchestration refers to the activities of lead actors who connect participants, design networks, and manage relationships to achieve a common goal, without exercising direct control and formal authority (Dhanaraj & Parkhe, 2006). Unlike traditional hierarchical control, orchestration relies on relational influence, convening power, and the design of governance structures that enable collaboration among autonomous actors.

Network orchestration provides a useful lens to understand how collaboration and coordination unfold in multi-actor settings and across multiple levels. The orchestration literature builds on studies on networks and ecosystems that investigate the relationship between collaborative arrangements and collective capabilities (Dhanaraj & Parkhe, 2006; Perks et al., 2017). Foundational contributions emphasize the articulation of capabilities and the recombination of resources as key mechanisms to generate innovation, foster development, and generate collective impact (Kalra & Roehrich, 2024; Paquin & Howard-Grenville, 2013). Orchestration typically entails three main processes: initiating and connecting network members, structuring and governing actors' collaboration, and sustaining and monitoring outcomes (Dhanaraj & Parkhe, 2006). These processes involve designing the network architecture, managing network members and relationships, facilitating knowledge flows, and balancing coherence with participant engagement (Perks et al., 2017).

In the context of grand challenges, orchestration faces unique complexities: the scale and heterogeneity of actors, the multiplicity of goals, and the unconventional nature of solutions make orchestration and coordination particularly demanding. In our research, we explore orchestration as a multi-level phenomenon: at the interpersonal level, we

investigate how individuals interact, share information and knowledge; at the organizational level, orchestration concerns how organizations manage resources, roles, and processes to support collaboration; at the network level, it examines how orchestrators design and steer inter-organizational structures to sustain collective action and scale impact.

In sum, our theoretical framework connects grand challenges literature and inter-organizational network theories into a coherent multi-level perspective. This approach enables us to understand how orchestration mechanisms facilitate coordination and collaboration across interpersonal, organizational, and network domains. Ultimately, we aim to offer both theoretical and practical insights into how large-scale, multi-stakeholder initiatives can be effectively managed to address pressing societal challenges.

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3. Methodology

The methodology underpinning this thesis is grounded in a constructivist and practical realist paradigm through which we developed and implemented a qualitative, multi-level methodological approach. This approach enabled us to conduct a comprehensive exploration of grand challenges through the lens of orchestration for collective action, examining how coordination unfolds across multiple levels of interaction. Specifically, we distinguish three interrelated levels: the interpersonal level (i), focusing on how individuals engage, share knowledge, and coordinate collaborative efforts; the organizational level (ii), examining how organizations manage resources, roles, and structures to support collaboration; and the network level (iii), where orchestrators design, govern and sustain interorganizational networks to enable effective collective action. By integrating these levels, we aim to uncover the mechanisms through which orchestration aligns distributed efforts, transforms individual and organizational behaviors, and translates them into effective collective outcomes. Adopting this multi-level perspective allows us to understand how coordination mechanisms transform individual intentions into collective outcomes, linking micro-level interactions with macro-level societal impact.

3.1. Empirical context

Our empirical context is represented by the *LIFE Bear-Smart Corridor project (BSC),* an environmental safeguarding initiative taking place in central Italy that aims to create and promote a model of '*coexistence'* between humans and wildlife. The BSC involves a network of actors characterized by distinct institutional logics and belonging to diverse institutional fields, such as public, private, for-profit, and non-governmental organizations (NGOs). These actors collaborate to design and implement a long-term strategic plan that seeks to balance ecological objectives with socio-economic needs, support nature-based enterprises, promote sustainable tourism, and enhance public awareness of biodiversity and the capability to coexist with nature and wildlife.

The BSC operates within a global scenario where natural ecosystems, critical sources of food, clean air, and water, and habitat for countless species, are threatened by human

activities and climate change. Such pressures, including mass tourism and deforestation, disrupt ecosystems, endanger biodiversity, and expose millions of species to the risk of extinction. Addressing these challenges is urgent and essential, as ecosystems support the economic, ecological, recreational, cultural, and scientific dimensions of human lives. In line with the Sustainable Development Goals, fostering responsible human activities and engaging local communities becomes crucial to sustaining healthy ecosystems and promoting human well-being (United Nations, 2015).

Central Italy is notable for the presence of the oldest national park that operates in an extensive territory where humans coexist with wildlife. The presence of several species, particularly bears, embodies the complexity of the project's goals and often represents a source of tensions. On one hand, they require continuous protection and monitoring through specialized technical operations conducted by designated organizations; on the other, they represent a potential driver for experiential tourism capable of generating economic opportunities for local communities and enterprises. Simultaneously, the bears' presence can also generate concerns among residents. These diverging perspectives highlight the coexistence of ecological, economic, and social interests within the same ecosystem of actors.

Advancing coexistence means fostering harmony among species, protecting natural ecosystems, and ensuring their accessibility while preventing exploitation and harm. Therefore, organizations, national parks, NGOs, local enterprises, municipalities, and residents form a complex collaborative network that pursues the shared objective of environmental and wildlife protection. Their diverging perspectives are embedded in the projects' initiatives, where lead organizations play a central role in orchestrating the action of the diverse stakeholders. Among the actors involved in the BSC, three lead organizations act as key orchestrators of the initiative: the National Park of Abruzzo, Lazio and Molise (PNALM), Rewilding Apennines (RA), and *Salviamo l'Orso* (SLO). Together with several local and non-local partners, these organizations are committed to advancing innovative approaches to environmental conservation through initiatives such as Bear-Smart Communities and Coexistence Corridors. Their joint efforts aim to develop and scale these models across European contexts while promoting the sustainable development of their territories. Through deliberate coordination mechanisms, they integrate knowledge and resources, align decisions across levels, facilitate cross-unit and

cross-sectors multi-level collaboration, and foster joint problem-solving. As a result, collective action emerges between individual and organizational contributions that become intentionally aligned toward the shared objective, leading to collective outcomes such as biodiversity protection and local socio-economic development.

Within this broader context, the first paper of this work, by focusing on the interpersonal level, explores the internal dynamics and coordination processes within PNALM. It investigates how park members collaborate, share knowledge, and manage operations across dispersed units to address complex environmental operations. The second, focused on the organizational level, analyzes the infrastructures of collaboration that connect PNALM with other key stakeholders. It explores how organizational structures and processes facilitate cooperation across institutional boundaries. Last, the third paper extends the analysis to the broader ecosystem of actors involved in the BSC initiative by focusing on lead organizations and collective stakeholders' interactions, negotiations, and alignment of resources and goals to sustain long-term collective action.

Together, these studies provide a comprehensive, multi-level understanding of orchestration within the BSC initiative, revealing how coordination mechanisms evolve and scale from intra-organizational collaboration to inter-organizational structures and, ultimately, to the governance of complex networks that engage multiple communities and institutional fields, thereby advancing progress for the grand challenge.

To collect rich insights from the empirical context, we were actively involved in the activities of the organizations within the network on multiple occasions throughout the course of the research. Environmental safeguarding involves a vibrant community composed of numerous experts and professionals, working alongside volunteers, collaborators, and anyone interested in learning and contributing. As researchers, we were granted the opportunity by the PNALM director and managers of the organizations involved to collaborate as volunteers, enabling us to engage deeply with the field while simultaneously collecting empirical insights.

3.2. Research Approach: Qualitative and Grounded Theory

This study employs a grounded theory approach (Eisenhardt, 1989) to capture the complex and evolving nature of orchestration in grand challenge initiatives. The research design combines inductive and abductive reasoning, allowing for the iterative interplay between empirical data and emerging theoretical insights. Data collection relied on multiple qualitative sources, including open-ended interviews and ethnographic observations, complemented by secondary materials such as archival records, official reports, and public documents. Our study focuses on three years of the BSC project and provides rich insight into the behaviors and interactions of the actors involved, as well as the coordination processes and the governance mechanisms across the collaborative network.

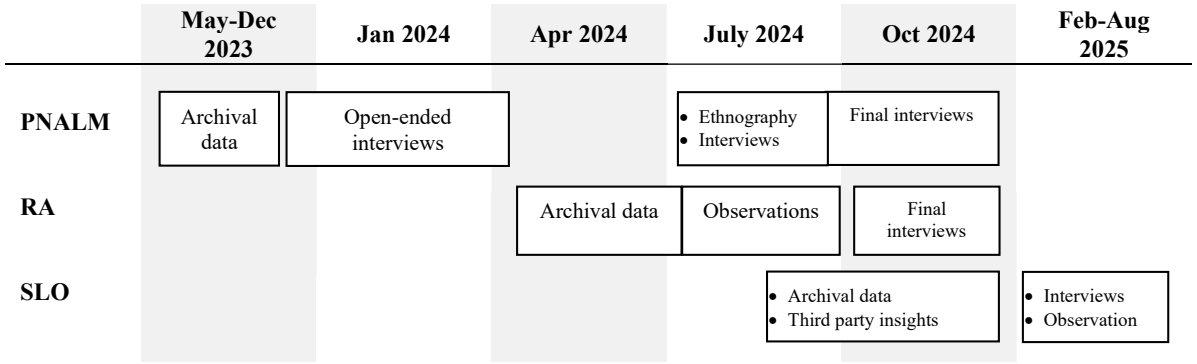
The analytical process involved document and content analysis, structured around open, axial, and selective coding. This iterative coding strategy facilitated the identification of core categories and the mapping of relationships among them, ultimately enabling the development of an explanatory model that illustrates how multi-level collaboration and orchestration dynamics unfold within the context of grand challenges.

3.3. Data collection

The collection of qualitative data aims to build a comprehensive understanding of the dynamics of collaboration within grand challenges contexts. We conducted a multi-level case study to explore in depth how a network of heterogeneous actors shapes collaboration and achieves coordination for a collective outcome.

We relied on multiple data sources, including secondary data, open-ended interviews with network members, and participatory observations, which also comprised a second round of more in-depth interviews. Data collection spanned 18 months, beginning with secondary data collection in May 2023 and concluding with the final interview in April 2025, and it is articulated in 5 phases. A graphical representation is reported below, and details are in the appendix of this section.

FIGURE 1 Data collection timetable



We collected comprehensive and insightful primary and secondary data to develop a nuanced understanding of the collaborative efforts necessary to implement the initiative, as well as the role of multiple actors and the surrounding community in driving progress within the context of grand challenges.

The document analysis of secondary data represented the preliminary phase, finalized to acquire a general understanding of the context and identify key players. Secondary data covered reports and published articles, including annual and scientific reports, articles, newspapers, posts, scientific studies, and datasets. This archival research provided the background to approach the subsequent stage of data collection.

The interviews comprised two major components, conducted between July 2023 and April 2025. These components included open-ended interviews and ethnographic interviews, through which we collected primary data from representatives of organizations involved in the initiative under investigation. In total, 34 interviews were conducted: 24 open-ended interviews were with PNALM members with diverse roles and backgrounds, including the director, managers, rangers, biologists, and stakeholders from the private sector, including enterprises and other actors; 9 interviews with RA representatives and stakeholders; and 1 interview with SLO. These interviews provided valuable insights to inform our inter-organizational perspective and deepen our understanding of the surrounding community. In total, these interviews amounted to 19 hours and 50 minutes and were guided by structured protocols, as detailed in the Appendix. All interviews were recorded, transcribed, and systematically analyzed to identify relevant themes and relations.

To gather richer insights, we have directly engaged in the activities: first, participant observation was conducted with PNALM through an eight-day volunteer program, and second, with RA during a monitoring operation. Participation in PNALM's activities was authorized by the Director, allowing the author to engage in daily operations and collect detailed field notes as an active participant. Similarly, the RA Team Leader allowed participation in their activities as a volunteer. These participatory observations provided rich data and a deeper understanding of the local context, offering valuable insights into social dynamics and facilitating connections with diverse stakeholders. Ethnographic interviews were conducted during this ethnographic phase with PNALM and RA members, as well as their stakeholders, including private-sector actors and volunteers. Data were recorded as field notes and systematically expanded daily through the development of an out-of-the-field dictionary (Van Maanen, 1988; Walford, 2009). This approach enabled a comprehensive understanding of both organizational dynamics and the surrounding social context.

Finally, qualitative data were iteratively compared with evidence from the literature throughout the data collection phase. In addition, data from interviews were triangulated with participant observations and archival sources, including reports, policy documents, press articles, and news items. This triangulation facilitated an in-depth understanding of relationships, resource sharing, power dynamics, and actions within and beyond the lead organizations.

3.4. Data analysis

Our analytical approach is based on qualitative analysis and the grounded theory approach (Strauss & Corbin, 1999). Through these approaches, we analyzed field notes, interview transcripts, and secondary data using inductive and abductive theory-building to capture emerging patterns and relationships and develop the case studies. The empirical evidence collected enabled the development of theoretical models to understand how coordination and orchestration mechanisms in our context are under exploration. The following provides an overview of the data analysis, which is presented in greater detail within each chapter of this manuscript.

To explore the coordination of actors across multiple levels in the contexts of grand challenges, we initially conducted a systematic analysis of secondary data, including reports, policy documents, press articles, agreements, and news, which were systematically organized into thematic categories. We then performed content analysis, applying open, axial, and selective coding (Strauss & Corbin, 1999), to identify patterns and relationships relevant to the research focus.

At the interpersonal level, we employed a qualitative, interpretive research design, combining content and co-occurrence analysis to examine relationships among interaction types and learning forms, to understand how these processes shape knowledge-sharing dynamics in the contexts of grand challenges.

At the organizational level, we conducted a qualitative in-depth case study, using content analysis based on open coding to identify challenges, dimensions, and roles related to how organizations manage data in complex multi-actor contexts. Furthermore, co-occurrence analysis was applied to reveal the configuration of organizational, digital, and technical dimensions within the data value chain across organizational and collaborative efforts.

Finally, at the network level, our approach involved a qualitative in-depth longitudinal case study. This investigation is developed through abductive reasoning, which entails iteratively moving between empirical observations and theoretical insights to refine explanations and develop robust conceptual understanding. We applied content analysis, including open, axial, and selective coding (Strauss & Corbin, 1999) to systematically identify thematic concepts, establish relationships among categories, and aggregate them into dimensions to understand how network orchestration unfolds in collaborative inter-organizational contexts addressing grand challenges. The process is illustrated through the development of a grounded theory model, following the Gioia methodology (Gioia et al., 2013; Magnani & Gioia, 2023).

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***Appendix a**: Preparation of the interview and ethnographic questionnaires and methodological overview*

The appendix outlines the process followed in designing the questionnaires and collecting the qualitative data employed in this study. The questionnaires were intended to support the exploratory investigation and capture rich insights within the context under study.

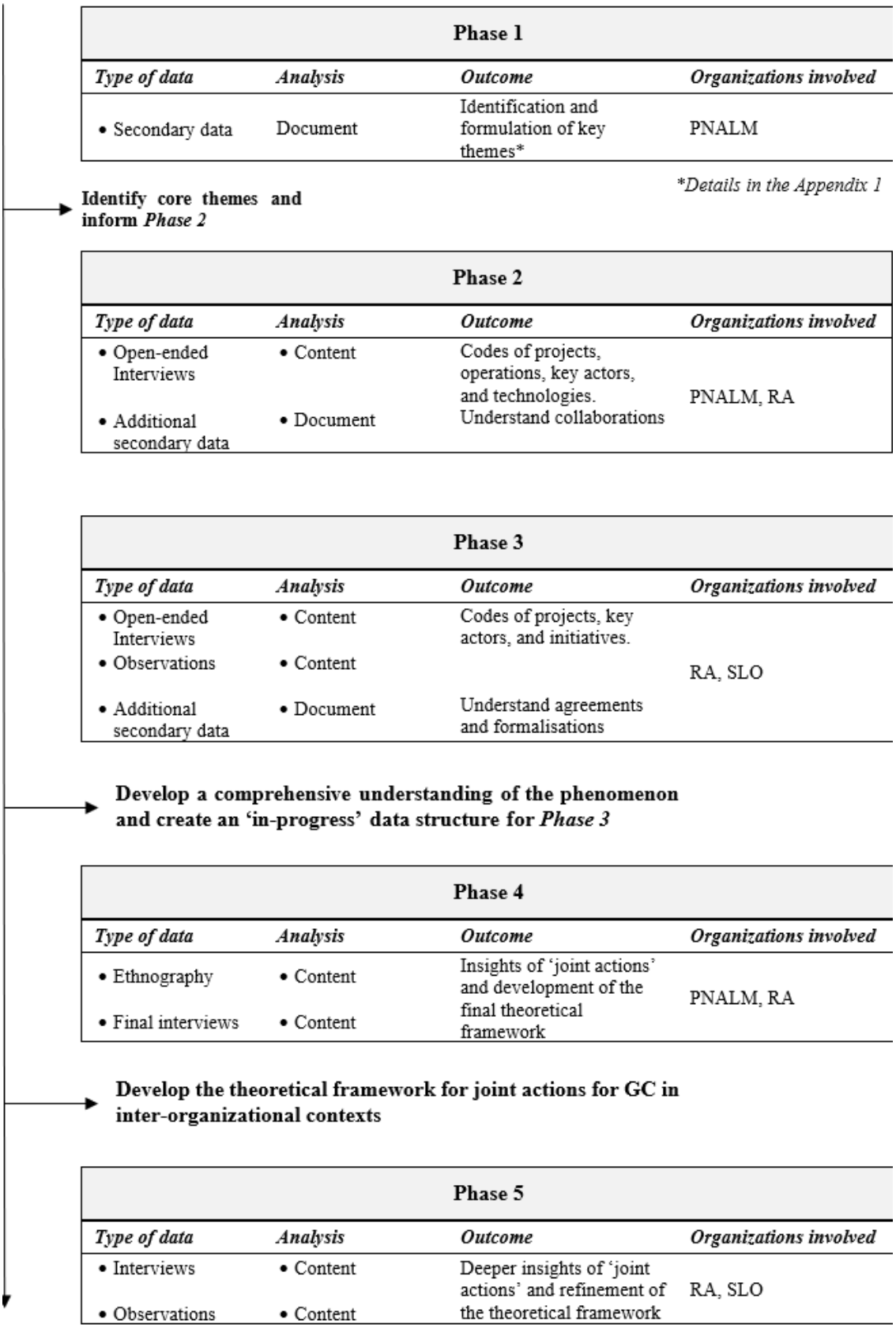
TABLE 1 Open-ended interview questionnaire

Category	**Questions**
Introducing questions	• Can you briefly illustrate the organization and its main objectives? • Can you describe the main activities and how they are carried out?
Monitoring	• In relation to the main activities, how important is monitoring and the correct collection of information? • Can you briefly explain how the necessary information is collected? • Given the large extent of the organizational territory, how are the various organizational units and their activities coordinated?
Technologies	• Has the organization adopted specific technologies over the years? • What type of data and information does the organization produce and use? • Which technologies are used to collect and manage the necessary data?
Personal Relationships	• Which units and actors do you interface with to carry out the activities? • How does communication take place? Could you describe how these relationships are organized? • How does the exchange of information occur?
Information sharing	• Which methods do you use for communicating and exchanging information? • How do technologies support coordination? In which activities? • Can you describe how these processes take place?
Learning	• How did you learn to do this work? How did the training take place? • Could you tell me about a moment when you realized you were learning? • Could you provide me with some examples of what you have learnt? Which tools were involved in the process?
Further questions	• Are there any emerging technologies that the organization is considering adopting? • If yes, which ones and why?

TABLE 2 Ethnographic questionnaire

Category	**Questions**	
	Non-experts *(e.g., volunteers, assistants, tourists)*	***Experts*** *(e.g., managers, professionals)*
Introducing questions	· How did you first hear about this work/experience? · Why did you choose to take part? Did you enjoy your choice?	· What is meant by "*project name"* in your context and how is this mission pursued?
Initial involvement and activities	· What was your first approach like? Did you follow a specific path? With whom? · What kind of activities did you carry out?	· How did the project start? Were there initial meetings or planning sessions? · What were the first actions implemented?
Community and collaboration	· What are the main motivations for doing this work? What is the final goal? · Do you feel that this goal is shared by others?	· Who are the main stakeholders involved (e.g., local authorities, entrepreneurs, volunteers)? · Why is their involvement important? Can you give an example?
Learning experimentation	· What have you learned from this experience on a practical level? How? · Have you learned to use specific tools or technologies? · What communication tools have you used? Can you provide me with examples?	· What strategies or activities are used to achieve rewilding objectives? · How do your practices differ from those in other contexts or countries? · Are new technologies being used?
Values and shared meanings	· What does "protecting nature" mean to you? Can you give an example? · Have you always found support from others? · Do you feel part of a community sharing similar values? Any anecdote?	· What does "protecting nature" mean within your organization? · Is this idea shared by all, or does it vary among different actors?
Impact and outcomes	· Has this experience made you more aware of environmental issues? · Has it influenced your daily habits or perspectives on nature? · What does "protecting nature" mean to you now?	· What are the main outcomes or results of this project? · What do you consider the most effective ways to pursue this mission?
Further questions	· Will you carry this experience and its values with you? Would you recommend it to others? · Anything else you'd like to share about this experience?	· Are there future ideas or directions for this project? · Are there further opportunities for collaboration?

FIGURE 2 Methodological approach



***Appendix b**: Overview of primary and secondary data collection*

TABLE 3 Overview of primary data collection

Source	Type	Phase	Details
PNALM	Archival Data	· Preliminary	· Appendix 1
	Open-ended Interviews	· 1 step	· 16 open-ended interviews
	Ethnography	· Participant observation · Final interviews	· Fieldnotes · 8 open-ended interviews
RA	Archival Data	· Preliminary	· Appendix 1
	Open-ended Interviews	· 1 step	· 9 open-ended interviews
	Ethnography	· Participant observation	· Fieldnotes
SLO	Archival Data	· Preliminary	· Appendix 1
	Open-ended Interviews	· 1 step	· 1 open-ended interview
	Open-ended Interviews (*non-direct*)	· Multiple steps	· Third-party insights from partners

TABLE 4 Detailed overview of primary data

Interview schedule PNALM

	Step 1		
Date	**Actor**	**Role**	**Length**
			PNALM site
21/07/23	Wildlife Office Manager	Manager	1h 43m
21/07/23	Communication Office Manager	Manager	1h 10m
21/07/23	Volunteer Park Ranger	Newcomers	29m
21/07/23	PNALM Director	Director	49m
21/07/23	Park Ranger	Experienced	32m
			Remote
09/11/23	Park Ranger	Chief	30m
09/11/23	Auxiliary Park Ranger	Newcomers	1h 15m
09/11/23	Auxiliary Park Ranger	Newcomers	35m
11/11/23	Park Ranger	Experienced	1h
			PNALM site
13/11/23	Park Ranger	Chief	40m
13/11/23	Park Ranger	Chief	40m
13/11/23	Park Ranger	Experienced	40m
13/11/23	Biologist	Scientist	55m
			Remote
01/12/23	Technology Provider	Sustainability Manager	45m
01/12/23	Technology Provider	Sustainability Manager	45m
26/02/23	Park Ranger	Newcomers	51m
	Final step - Ethnography		
Date	**Actor**	**Role**	**Length**
			PNALM site
29/07/24	Park Volunteer	Unexperienced	44m
29/07/24	Park Volunteer	Unexperienced	44m
29/07/24	Park Volunteer	Unexperienced	44m
29/07/24	Park Volunteer	Unexperienced	15m
29/07/24	Park Volunteer	Unexperienced	15m
			Remote
20/08/24	Communication Office Manager	Manager	54m
20/08/24	Education Manager	Manager	54m
31/10/24	Volunteer Coordinator	Qualified	39m
Tot.	24 interviews		13h 47m

Interview schedule RA

Date	**Step 1**		
	Actor	**Role**	**Length** **RA Site**
01/07/24	Team Leader	Manager	57m
01/07/24	Enterprise Manager	Manager	57m
05/07/24	Volunteer	Unexperienced	37m
05/07/24	Volunteer	Unexperienced	37m
10/07/24	Operation Field Manager	Manager	44m
14/08/24	Enterprise Manager	Manager	51m
15/04/25	Team Leader	Manager	50m
15/04/25	Enterprise Manager	Manager	50m
30/04/25	Team Leader	Manager	2h
Tot.	9 interviews		6h 2m

Interview schedule SLO

Date	**Step 1**		
	Actor	**Role**	**Length** **SLO Site**
26/02/25	Coordinator	Head of activities	35m
Tot.	1 interview		35m

TABLE 5 Detailed overview of secondary data

Archival data

Type of data	*Description of data*	*Detail*	*Organization*	*Code*
Annual reports	Overview of operations conducted in collaboration with multiple actors	27 reports	PNALM	RPN1
Social report	Details of activities on a voluntary basis, beyond financial considerations	1 report	PNALM	RPN2
Project reports	Overview of ongoing and future projects and initiatives	5 brochures and articles 18 website pages	PNALM	RPN3
Tech implementation	Reports and media coverage on technology adoption and utilization	5 tech reports 9 website news 2 social posts	PNALM	TPN1
Organigram	Details of the organizational chart and strategic planning	1 chart 1 planning report	PNALM	OPN1
Scientific publications	Scientific papers involving nature management, economic efficiency, and sustainable tourism	14 papers and publications	PNALM	SPN1
Other publications	Flyers, promotional resources, FAQs, manuals, and maps	20 documents	PNALM	PPN1
Annual reports	Overview of collective achievements across all the rewilding landscapes to make Europe a wilder place	12 reports	RA	RRA1
Social report	Overview of people engagement and their roles in rewilding, beyond financial considerations	1 official webpage	RA	RRA2
Activity reports	Details of activities, projects, and initiatives carried out to make progress in rewilding	3 reports 10 official webpages 1 social post	RA	ARA2
Rewilding organizations	Details of the multilevel network involving ‘rewilding landscapes’ and ‘rewilding network’ to scale up	5 reports 10 ‘landscape’ webpages 17 ‘network’ webpages	RA	RRA3
Organigram	Details of the organizational chart and related human resources	1 chart	RA	ORA1
Scientific publications	Scientific papers involving the management of nature, nature-based economies, and sustainable tourism	5 papers 3 website papers 1 report	RA	SRA1
Other publications	Communications of meetings, posts, promotional resources, FAQs, and manuals	1 post 1 website page	RA	ORA2
Annual reports	Overview of achievements, activities, and financial situation	11 reports	SLO	ASO1
Statue reports	Documentation of the fundamental legal act that regulates the organization and functioning of the entity	1 report	SLO	SSO1
Social report	Overview of engagement efforts and awareness-raising activities	1 report	SLO	SSO2
Organigram	Details of the human resource organization	1 official webpage	SLO	OSO1
Publications	Comprehensive online archive of publications, news, media, and articles	1 archive (comprehensive) 1 report and 4 pages	SLO	PSO1
Collaboration agreements	Details of collaboration activities and focal actors within the territory	15 collaboration reports 9 website news	PNALM, RA, SLO	CA00
Total		218 documents		

PART II: Orchestrating for Grand Challenges

Part II of this thesis consists of the three papers, preceded by a brief introduction that illustrates the general theme, the contributions of the co-authors, and the stage of publication.

4. Paper I: On Knowledge Sharing in Dynamic Work Environments: Lessons Yet to Be Learned [1]

The following paper examines how diverse interpersonal interactions support tacit and explicit knowledge sharing and foster different forms of learning, within the context of the National Park of Abruzzo, Lazio and Molise (PNALM), where staff and volunteers address high-stakes, unpredictable human–wildlife coexistence issues. It is based on ethnographic observations and interviews and illustrates how dispersed teams coordinate across ordinary, situational, and critical activities and enable knowledge creation.

This paper is written in collaboration with Prof. Federica Ceci and Prof. Francesca Masciarelli from the G. d'Annunzio University.

This paper has been submitted to the *Knowledge Management Research & Practice* Journal and is currently under the first round of review.

[1] Paper written in collaboration with Federica Ceci and Francesca Masciarelli - G.d'Annunzio University

Abstract

Effective knowledge sharing requires organizations to identify, combine, and utilize members' experiences to make knowledge accessible to others. Interpersonal interactions within work activities play a fundamental role in driving knowledge sharing, ultimately enhancing individual learning. However, as work becomes increasingly characterized by dynamic environments, time constraints, knowledge-intensity, and uncertainty, exclusive traditional learning becomes poorly viable. In complex 'high-stakes' work contexts, such as those involving extreme environments, hazards, environmental initiatives, or knowledge-intensive sectors, knowledge sharing demands careful adaptation, appropriate tools, and the required level of information detail for specific situations. Through the development of a case study focused on the National Park of Abruzzo, Lazio, and Molise (PNALM), we investigate how diverse forms of interpersonal interactions support the sharing of tacit and explicit knowledge, ultimately facilitating different types of learning – reflexive, experimental, contextual, and vicarious learning. We demonstrate how this process unfolds across a range of activities, from ordinary tasks to unpredictable situations, and is coordinated through various communication tools. This paper contributes to the research on learning and knowledge sharing by providing a conceptual model that illustrates how knowledge sharing is situated in interactions, tools, and practices in increasingly complex work environments.

Keywords. knowledge sharing, learning, interactions, communication, tools, groups.

Introduction

Over the past decades, research on knowledge management and learning has highlighted the importance of knowledge as a fundamental asset for organizational performance and competitive advantage (Argote & Ingram, 2000; Davenport & Prusak, 1998). Knowledge creation, often regarded as the core of learning in organizations, is shaped through ongoing social interactions occurring at individual, group, and organizational levels (Nonaka, 1991). As this knowledge emerges and evolves, it becomes embedded in organizational routines, memory systems, and shared practices, enabling it to circulate and drive further learning and adaptation across multiple levels of the organization (Kogut & Zander, 1992; Seely Brown et al., 1997; Argote et al., 2021). Knowledge sharing is not only a process of exchange, but it is also deeply rooted in the organizational context, which shapes both internal and external conditions that may influence individuals' experiences. These experiences may vary depending on interpersonal interactions, types of activities undertaken, and level of collaboration among individuals, all of which play a role in facilitating or hindering learning (Argote & Miron-Spektor, 1999).

As organizations engage in dynamic work environments characterized by time constraints, complex operations, or knowledge-intensive tasks, often involving distributed members, or unpredictable situations, the need to continually learn becomes crucial (Myers, 2022; Sole & Edmondson, 2002). In these contexts, organizations require seamless coordination, continuous information exchange, and extensive domain-specific expertise to address increasingly harder challenges. While learning is facilitated by shared practices among individuals, the distributed and complex nature of these operations may render its process impractical or less effective, particularly when it relies solely on personal experience or standard knowledge management systems (Myers, 2022; Tyre & Von Hippel, 1997). Under such conditions, traditional learning strategies and standardized organizational systems for capturing and transferring knowledge become increasingly unviable.

Organizational literature has widely explored how knowledge-sharing mechanisms enhance learning, experience, and know-how accumulated over time. Extensive research has investigated how tacit and explicit knowledge is shared through individuals' interactions within different organizational contexts and levels (Hansen et al., 2005;

Lemmetty & Collin, 2020; Nonaka, 1994; Nonaka & Takeuchi, 1995; Pisano, 1996). This body of work assumes that knowledge sharing strengthens individual and team capabilities, know-how, and skills, thereby fostering innovation, competitive advantage, and improved performance (Cabrera & Cabrera, 2002; Davenport & Prusak, 1998; Wang & Noe, 2010). However, the evolving nature of work in today's dynamic environments, such as extreme settings, hazardous conditions, environmental initiatives, or knowledge-intensive sectors, demands additional planning, consideration, and appropriate tools for knowledge sharing within specific situations. This makes existing literature, which focuses more on traditional and more stable settings, less effective in explaining how knowledge sharing occurs in such contexts. As these settings demand continuous collaboration, careful team coordination, extensive knowledge, and high levels of information, it becomes crucial to understand how, when, and by what means individuals actively enact knowledge sharing, ultimately driving learning. In this paper, we investigate the role of interpersonal interactions as a knowledge-sharing mechanism in fostering individual learning. We explore this relationship within a dynamic work environment, characterized by rapid and unpredictable events, turbulent change, or challenging demands to human cognition and decision-making (Eisenhardt & Bourgeois, 1988; Eisenhardt & Martin, 2000; Hitt et al., 2010; Sutcliffe, 2007; Vicente et al., 2001; J. Wang, 2021). Within such environments, organizations are often characterized by dispersed team operations, simultaneous and coordinated activities, vast, harsh environments, time constraints, and the frequent need for quick decision-making, aspects that make learning essential yet difficult to attain (Myers, 2022; Patel et al., 1996; J. Wang, 2021).

Prior research has highlighted the importance of understanding mechanisms that enhance knowledge sharing (Crossan et al., 1999). Accordingly, knowledge is context-specific, shaped by social interactions and distributed collectively across individuals (Brown & Duguid, 2001; Davenport & Prusak, 1998; Lave & Wenger, 1991; Nonaka, 1994). It is embedded into artifacts and manifests through externalization within processes and practices (Bosua & Scheepers, 2007; Nonaka et al., 2006). Its sharing is influenced by the complexity and intrinsic characteristics of the environment, such as team dispersion, role definitions, technological implementation, and the generational change of workers (Bosua & Scheepers, 2007; Muniz et al., 2024; Prentice et al., 2025; Sole & Edmondson,

2002; Tyre & Von Hippel, 1997). Despite the extensive insights provided by literature into these relationships, how diverse forms of individual interactions within a dynamic work environment function as knowledge-sharing mechanisms remains unclear. In such contexts, interactions can take various forms, ranging from personal and digitally mediated interactions to different types of engagement in multiple activities. Here, interpersonal interactions may vary widely: they can occur face-to-face or through digital channels. Additionally, interactions may involve different groups engaged in activities of varying nature, including informal discussions, structured meetings, or activities requiring immediate response, such as emergency interventions. Therefore, in these complex scenarios, our understanding of how learning and knowledge sharing function is limited.

This study offers a qualitative exploration of how various forms of interpersonal interactions serve as knowledge-sharing mechanisms, fostering individual learning across teams of 'wildlife operators' engaged in environmental safeguarding efforts within the National Park of Abruzzo, Lazio, and Molise (PNALM). This setting constitutes a dynamic work environment, as it encompasses key characteristics such as rapid and unpredictable events, high demands on human resources, and quick decision-making. Moreover, it often requires dispersed team operations and simultaneous and coordinated activities across a challenging and vast territory. Nestled in Central Italy, the National Park plays a vital role in managing the local complex wildlife through the implementation of dedicated strategies and collaborative efforts of its members. Wildlife operators include park rangers, biologists, researchers, educators, and highly qualified personnel, frequently joined by a renewed workforce including auxiliaries and volunteers of different levels of expertise. By working within the dynamic environment of the National Park, teams engage in a variety of critical activities ranging from wildlife monitoring and census to the surveillance of delicate situations, such as managing animal incursions into human settlements, addressing unpredictable confident behaviors, or responding to emergencies in hard-to-reach areas. These teams operate within a vast high-stakes environment, dealing with time constraints and limited information, while managing human-wildlife coexistence within the uncertainty of situations.

As traditional learning proves to be impractical in such contexts, interpersonal interactions assume crucial importance for knowledge sharing. PNALM thus provides a

rich and relevant empirical setting for examining how knowledge sharing and learning adapt to the complex and demanding conditions of a dynamic work environment. In these environments, formal learning is often neither sufficient nor feasible. Therefore, we investigate how learning spontaneously occurs under such challenging conditions through activities that require continuous interaction and knowledge exchange, both mediated and unmediated, often occurring directly in the field. This is particularly critical in PNALM, where the constant involvement of new auxiliary staff and volunteers in these activities makes ongoing knowledge sharing essential yet difficult to achieve. Therefore, in light of this, we ask: *How do interpersonal interactions enable knowledge sharing within the dynamic work environments of grand challenges? How does learning unfold in such contexts?*

Drawing on ethnographic observations and interviews with park members, we develop a conceptual model to explore how interpersonal interactions enact learning through knowledge sharing. We demonstrate how this process unfolds across a range of activities, from ordinary tasks to unpredictable situations, coordinated through various communication tools, and involving members with varying degrees of experience in the field. As these activities require thorough knowledge about the wildlife and the environment, all the employees are in a condition of continuous learning, especially due to knowledge sharing between experts and newcomers. We demonstrate how these different forms of interaction aim to prepare newcomers for future activities, while simultaneously enhancing the success of current ones by extending the transfer of knowledge across all levels of the organization for future challenges.

The remainder of the paper is structured as follows: first, we introduce knowledge sharing and learning literature to provide the background of this study. The following section presents the research design, including the empirical context, the data collection, and analysis. In the conclusion, we highlight our contributions, discuss the limitations, and identify directions for future research.

Literature review

Knowledge sharing and social interactions

Before delving into the core of this study, a brief historical overview of the concept of knowledge is provided. The academic literature defines knowledge as a human asset that emerges as a result of complex and accumulated expertise, residing in individuals and embedded into social contexts (Davenport & Prusak, 1998; Grant, 1996; Nonaka, 1991; Nonaka & Toyama, 2003; Seely Brown et al., 1997). Davenport and Prusak (1998, p.4) describe knowledge as '*a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information*'. Within this perspective, the individual acts as an agent capable of creating knowledge and, through interactions with others, facilitates its dissemination across all levels of the organization (Nonaka & Takeuchi, 1995).

Over the years, multiple perspectives have acknowledged the role of experience in shaping human knowledge encompassing action, expertise, and know-how, thereby emphasizing the role of the 'human body' being situated in the world (Nonaka & Toyama, 2003; Polanyi, 1967; Sole & Edmondson, 2002). In his research, Polanyi (1967, p. 4) introduced the idea that '*we know more than we can tell'*, laying the foundation of the concept of an 'unspeakable knowing' later labelled tacit knowledge. Tacit knowledge refers to beliefs, mental models, and individual perspectives that are difficult to formalize or share with others (Nonaka, 1994; Polanyi, 1967). Tacit knowledge resides in the human mind and cannot be easily captured or managed, yet it manifests through actions. By definition, tacit knowledge is inherently difficult to identify, capture, and report, as it is deeply embedded in action and context. In contrast, explicit knowledge, its more accessible counterpart, can be articulated through words or numbers and represents a minimal part of the existing knowledge. Explicit knowledge is codified into formal language and is easily transferable across individuals and contexts (Nonaka & Toyama, 2003; Polanyi, 1967). Further advancements derive from the practice-based view of knowledge, which emphasizes the role of actions, experiences, and perspectives of others, highlighting social interactions as a lens through which to approach knowledge sharing (Brown & Duguid, 2001; Spender & Grant, 1996; Wang et al., 2006; Wenger, 2000).

Knowledge sharing is a process by which individuals access knowledge and information from social interactions occurring within a common context. It refers to the ability to transfer prior experience, information, know-how, and both explicit and tacit knowledge, making it accessible to others (Cummings, 2004; Hansen et al., 2005; Christensen, 2007; Kenneth, 2007). It enables individuals to enhance expertise, capability, and facilitates teams to develop a collective knowledge base (Bosua & Scheepers, 2007; Cabrera & Cabrera, 2002; Christensen, 2007; Dyer & Nobeoka, 2000; Thompson & Walsham, 2004; Wang et al., 2006). Nonaka (1998) emphasized the importance of the physical context for knowledge sharing, defining '*Ba'* as the space where knowledge is created and shared. This concept encompasses physical, virtual, and mental spaces, and provides the essential elements such as energy, quality, and place for knowledge exchange (Nonaka & Konno, 1998; Nonaka & Toyama, 2003). Similarly, Lin (2007) stressed the importance of the environment in fostering knowledge sharing by identifying how collaboration and openness are critical in facilitating this process. She underscores that knowledge sharing is shaped by organizational culture, trust, communication and mutual understanding, emphasizing the social interaction nature of this process.

Nonaka & Takeuchi (1995) argue that sharing knowledge with others necessitates close interpersonal interaction, which can vary across different dimensions depending on the context in which they occur (Nonaka & Konno, 1998; Nonaka & Toyama, 2003). According to the authors, the first dimension pertains to the type of interactions, whether they occur individually or collectively. The second dimension concerns the media used to facilitate the interaction, which can be either face-to-face or virtual. Several studies have explored how knowledge sharing occurs through social interactions, emphasizing how it is embedded in specific contexts and across various dimensions. For example, Dyer & Nobeoka (2000) investigated how Toyota established a network of employees, suppliers, and partners to facilitate the sharing of knowledge and best practices through a combination of face-to-face interactions and technology platforms. Liang & Suntrayuth (2024) examined the influence of relational social capital on employees' willingness to share knowledge in the workplace. In the Brazilian Glass Sector, Muniz et al. (2024) found that knowledge sharing relies heavily on workers' experience and expertise to maintain quality and foster innovation, given high levels of specialized and tacit knowledge characterizing the sector. Nakano et al. (2013) explored how tacit knowledge

is shared informally on the shop floor, with emphasis on engagement, collaboration, and trust among workers of varying degrees of expertise. Finally, Bosua et al. (2007) and Pandey et al. (2021) examined how knowledge sharing occurs in complex organizational environments. Bosua et al. focused on the challenges faced by large organizations in fostering knowledge flow across formal organizational units. They emphasized the role of organizational culture, communication channels, and technology to create an environment to support effective knowledge transfer. On the other hand, Pandey et al explored knowledge sharing within rural healthcare communities, underscoring how communication technologies help overcome barriers to knowledge exchange in this environment.

Technologies for knowledge sharing

The critical role of technology in enabling knowledge sharing has been widely acknowledged in the literature (Bordia et al., 2006; Castaneda & Cuellar, 2020; Neches et al., 1991; Razmerita, Kirchner, et al., 2016). Studies have investigated how technological tools facilitate knowledge exchange within organizations by enhancing internal communication and enabling the transformation of personal knowledge into a collective asset (Razmerita, Kirchner, et al., 2016; Razmerita, Wren, et al., 2016).

As organizations become increasingly complex, they tend to adopt a wide range of information and communication technologies to support knowledge sharing. These tools include messaging platforms, mobile calls, email systems, and more advanced technologies such as Internet of Things (IoT) devices, sensors, and real-time databases (Cantù & Corsaro, 2007; Ngah & Jusoff, 2009; Paroutis & Saleh, 2009). Such technologies are implemented to support a continuous flow of information and interpersonal interactions, which are essential for navigating the work environment. More specifically, digital technologies support interpersonal interactions and the flow of knowledge by increasing internal connectivity among individuals and teams. These tools also improve the quality, accessibility, and distribution of information, allowing individuals to access knowledge anytime and anywhere, thereby sustaining operations, strategic activities, and innovation processes (Castaneda & Cuellar, 2020; Ceci et al., 2021; Neches et al., 1991; Paroutis & Saleh, 2009). In doing so, digital technologies help to reduce coordination costs and operational inefficiencies, while fostering an

environment favourable to collaborative learning and continuous knowledge exchange (Castaneda & Cuellar, 2020; Pandey et al., 2021).

Research has demonstrated that knowledge sharing is influenced not only by the technological infrastructure supporting interpersonal interactions, but also by the structure of relational networks within the organization (Bock et al., 2005; Hansen et al., 2005; Nakano et al., 2013). In this regard, both the strength of interpersonal relationships and the type of technology in use can significantly affect how knowledge is exchanged and integrated across teams.

Knowledge sharing and learning in dynamic work environments

Scholars widely recognize that knowledge sharing plays a fundamental role in fostering learning, enabling the diffusion and transformation of knowledge within organizations (Argote & Miron-Spektor, 1999; Choi, 2013; Yang, 2007). Learning is defined as a process that modifies the views and behaviors of an individual through experience (Argote & Miron-Spektor, 1999). While early studies primarily referred to learning as an individual-level construct, contemporary perspectives emphasize its social nature, highlighting the role of interpersonal interactions among individuals and groups in sharing knowledge and enhancing their collective experience (Argote & Miron-Spektor, 1999; Harvey et al., 2023; Seely & Duguid, 1991; Wenger, 2000).

The ontological perspective on how knowledge is embedded within organizations frames organizational learning both as an individual and collective phenomenon. From the individual perspective, learning is a cognitive or behavioural activity in which individuals develop mental models and experience through observation, intuition, and interpretation of the environment (Bennet & Bennet, 2004, 2008; Bontis et al., 2002). From the collective perspective, learning refers to the 'social construction' of a common understanding among groups within organizations (Brown & Duguid, 2001; A. Edmondson & Moingeon, 1998). Collective learning is grounded on the willingness of organisational members to learn and access knowledge, thereby fostering organizational adaptation to uncertainty, problems, and change (Argote, 2024; Argote & Ingram, 2000a; Edmondson, 2002; Harvey, Bresman, Edmondson, et al., 2018; Wilson et al., 2007).

The academic literature identifies distinct categories of learning shaped by the way knowledge is constructed and shared through social processes and experiences within specific settings. These categories include contextual, experimental, reflexive, and vicarious learning. Contextual learning is a form of learning that enables individuals to draw lessons from external sources, relying on the specific context in which they are learning (Bresman, 2010). Reflexive learning involves activities where individuals analyze and evaluate past information, experiences, or situations, enabling them to improve the efficiency and quality of the outcomes of their work (Edmondson, 2002; Harvey, Bresman, & Edmondson, 2018). Typically occurring in internal, exploitation-oriented activities, it drives performance improvements by evaluating past events (Harvey, Bresman, Edmondson, et al., 2018b). In contrast, experimental learning involves action preceding cognition (Crossan & Sorrenti, 1997) and occurs when individuals gain new knowledge or insights through experimentation or testing (A. C. Edmondson, 2002). Finally, vicarious learning allows individuals to learn from the experience of others with prior experience of who is learning (Bresman, 2010; Myers, 2021). In summary, learning is recognized as both an individual and a collective phenomenon where knowledge is embedded into the social context and reflects how individuals apply it in practice (Brown & Duguid, 2001).

Despite prior research has highlighted the importance of knowledge sharing mechanisms to enhance learning and acknowledged their context-specific and collective nature, limitations remain. While extensive literature has provided valuable insights into these relationships, how diverse forms of individual interactions function as knowledge-sharing mechanisms within a dynamic work environment remains underexplored. Characterized by degrees of rapid, unpredictable, and turbulent changes, dynamic environments often generate complex nonlinear relationships, inaccurate predictions, and wrong expectations (Eisenhardt & Bourgeois, 1988; Eisenhardt & Martin, 2000; Hitt et al., 2010; Sutcliffe, 2007). In such contexts, interactions can take various forms, ranging from personal and digitally mediated interactions to different types of engagement in multiple activities. Interpersonal interactions may involve different groups engaged in various activities, such as informal discussions, structured meetings, or activities requiring immediate response, such as emergency interventions and occur face-to-face or mediated by digital channels (Bosua & Scheepers, 2007; Cantù & Corsaro, 2007; Maanen & Kolb, 1982; Muniz et al.,

2024; Myers, 2022; Pandey et al., 2021). Given that these diverse forms of interactions can influence how knowledge sharing occurs, it becomes crucial to understand how interpersonal interactions shape and impact on this process. Therefore, building on existing research, this paper investigates how interpersonal interaction in dynamic work environments fosters knowledge sharing, ultimately impacting learning in organizations. We aim to address this gap through the investigation of a dynamic work context involved in environmental safeguarding initiatives. This empirical setting provides an opportunity to observe a range of activities, from routine operations to unpredictable tasks, conditions that make learning essential yet challenging to achieve.

In such complex contexts, interpersonal interactions become crucial, serving as the primary driver of knowledge sharing, while traditional learning strategies prove impractical. We aim to explore how diverse forms of interpersonal interactions serve as key mechanisms for knowledge sharing and learning, crucial for fostering organizations to effectively address both present and future challenges.

Methodology

We adopted inductive, qualitative methods to explore the role of interpersonal interactions as a knowledge-sharing mechanism for individual learning in the dynamic work context of The National Park of Abruzzo, Lazio, and Molise (PNALM). Given the social nature of knowledge sharing and its deep connection to the context, a qualitative case study (Yin, 2003) allows for a comprehensive investigation of the phenomenon, capturing both collective behaviors and the dynamics of the environment where learning occurs.

Empirical context

The National Park of Abruzzo, Lazio and Molise is the oldest National Park in Italy, renowned for its richness in biodiversity. PNALM is home to the iconic Marsican bear, alongside other wildlife species such as the endemic Apennine chamois, the Apennine wolf, the deer, and the golden eagle. Together with many other species, they create an exceptional biodiversity. Over the years, the National Park has managed the wildlife of central Italy through dedicated efforts, including monitoring and surveillance, education programs, stakeholder engagement, and awareness initiatives. In this unique

environment, humans and animals share the same space: human settlements and vibrant wildlife are immersed within the untamed environment where PNALM effectively manages this delicate balance. Through dedicated strategies, specific activities, and collaborations, park members protect the rich biodiversity while safeguarding the well-being of the people living alongside the wildlife. Together, they share a living space where nature and human beings are intertwined.

Ensuring coexistence is a complex challenge that requires the implementation of diverse strategies based on wildlife monitoring, research, surveillance, and dedicated tasks. To carry out these activities, park management is entrusted to several organizational areas. These areas include technical, surveillance, scientific, veterinary, and educational areas that are involved in a wide range of activities, from monitoring and census to educational programs and the management of unpredictable or emergencies. The activities are conducted by 'wildlife operators' such as park rangers, biologists, researchers, and educators. They are highly qualified professionals, frequently joined by a renewed workforce composed of auxiliaries and volunteers with varying degrees of expertise. By working within the dynamic environment of the National Park, according to their level of expertise and training, they engage in a variety of critical activities ranging from wildlife monitoring to the management of delicate situations, such as animal incursions into human settlements, addressing unpredictable confident behaviors, or responding to emergencies in hard-to-reach locations. They operate within a vast high-stakes environment, dealing with time constraints, knowledge intensity, and uncertainty of situations. In such a complex context, interpersonal interactions assume crucial importance.

Operators and group structure

PNALM operators typically work in different formations, such as groups or multiple dyads, depending on the nature of the activities to be carried out. On the one hand, groups are composed of members with varying degrees of expertise, including highly qualified professionals, mid-level auxiliaries, and newcomers engaged in training programs. On the other hand, multiple dyads are typical formations for conducting activities out of the field, where a distributed organizational approach is required to achieve specific tasks such as simultaneous monitoring in displaced areas or for coordinated efforts across

multiple locations. They consistently rely on teamwork between expert operators and less experienced members, whose continuous interactions foster ongoing 'field-based' knowledge sharing. However, the dynamic and unpredictable nature of these complex operations makes effective knowledge sharing and learning particularly challenging to address. For instance, park operators must often have to deal with wildlife's 'confident' behaviors when bears venture into human settlements. This phenomenon demands particular attention and requires specific measures, such as 24-hour monitoring shifts or other specific forms of continuous observation. These measures demand deep knowledge of the surrounding environment and the species, the ability to make rapid decisions, and a strong commitment to trust and teamwork. Not only confident bear behaviors or emergencies, but even routine activities often require particular human, technical, and cognitive resources. Scientific research based on geo-localization, biological sample collection, or GPS-track mapping depends on deep knowledge and a dense network of interactions. These activities are supported by a range of technologies, from task-specific tools and data systems to various communication tools essential for coordination and information sharing. These tools include IoT radio-collars for wildlife localization, mobile apps for real-time data collection and sharing, databases, and analysis software for efficient data management, as well as mobile phones for coordination in remote areas. In addition, these technologies are complemented by traditional tools such as sighting cards to enrich data collection, binoculars, photo-traps, and night-vision devices to extend the range of observations.

The role of interactions

In this complex context, relationships among park operators form a network of entrenched interpersonal interactions, which unfold either personally or mediated by digital tools. These interactions can include conversations, informal discussions, and structured meetings, and may occur in a range of activities, from those requiring immediate response to routine tasks. These interactions assume crucial importance until becoming the principal driver of knowledge sharing, while traditional learning strategies prove to be unfeasible. Therefore, knowledge sharing unfolds across a range of activities, from ordinary tasks to unpredictable situations. Interpersonal interactions occur through various forms of communication tools and involve group members with varying degrees of experience. As these activities demand in-depth knowledge of the wildlife and the

environment, all members are in a condition of continuous learning. PNALM is a unique context where interpersonal interactions become the principal driver of knowledge sharing among individuals operating within an uncertain, dynamic work environment. They present and share a deep knowledge of the surrounding natural environment and the species, the capacity to make decisions in a short time, and a high propensity for teamwork. The characteristics of the context compel continuous learning, particularly through hands-on experience in the field. Additionally, a strong heritage of tacit knowledge, often difficult to articulate or share, combined with the extensive use of technologies, makes learning particularly interesting yet challenging. Operators must therefore engage in diverse, uncommon forms of learning to capitalize on their knowledge.

The unique and demanding environment in which these activities take place, alongside the critical role of interactions and technologies, makes this setting ideal to observe how knowledge sharing and learning unfold.

Data collection

Phase 1: archival data. We collected secondary data, including strategy reports, articles, newspapers, posts, scientific studies, and datasets, to gather valuable information from published sources. These data concern several sources, including official website, social pages, newspapers, Scholar and Scopus databases, and open data platforms – Natura 2000 dataset and OpenData *Regione Abruzzo*. This phase involved the collection of various types of secondary data, such as annual, social and project, and technology implementation reports, scientific publications, and the organization's structure. More particularly, we collected an overview of operations, activities, ongoing initiatives, technology adoption, and publications totaling 103 documents. We organized these data into emerging topics to gather valuable information from multiple sources (see Appendices b for further details). The primary purpose of phase 1 was to prepare for the subsequent phase of interviews, enabling a more informed and targeted approach.

Phase 2: interviews. Primary data were collected through open-ended interviews, beginning with general questions about the interviewees' first experiences and their career paths. The questionnaire included introductory questions followed by five sections: monitoring activities, technology use, personal relationships, information sharing, and

personal learning experience, with concluding questions at the end of each session. A total of 16 interviews were conducted with PNALM members from various roles and backgrounds, including the director, managers, scientists, rangers, auxiliaries, volunteers, and external actors. The first five interviews took place in July 2023, with the second stage conducted over two months, in October and November of the same year. The initial interview lasted 2 hours, and subsequent interviews lasted approximately 1 hour each, spanning a total of 11 hours and 14 minutes. Appendix b highlights the interview details, including locations, involved actors, their roles, and the duration of each interview. All interviews were recorded, transcribed, and coded to identify relevant topics and develop the case study. Appendix III presents the interview questionnaire.

Phase 3: ethnography. The Director of PNALM granted us permission to participate as volunteers in the activities for a period of 8 days. During this time, we gathered detailed data through participatory observations, focusing on the interpersonal interactions, relationship dynamics, and the technologies in use. These observations were documented as fieldnotes and later expanded through out-of-the-field notes (Van Maanen, 1988; Walford, 2009). This approach enabled us to capture a comprehensive understanding of the social dynamics and knowledge sharing. Finally, by triangulating data from multiple sources, we were able to enhance the reliability of our findings. Table 6 summarizes our primary data sources.

TABLE 6 Overview of primary data collection I

Type of data	Actors	Location	Duration
16 open-ended Interviews (*11h 14m*)	• Director, managers, rangers • Chief ranger, rangers, auxiliaries • Rangers, biologist • Tech. providers, ranger	• PNALM Site • PNALM Site • Remote call • Remote call	• 5 interviews, 4h 43m • 4 interviews, 3h 20m • 4 interviews, 1h 35m • 3 interviews, 1h 36m
Observations (*192h*)	• PNALM members • Me (volunteer, researcher)	PNALM Site	17 pages of field notes

Data analysis

Our protocol is grounded in inductive methods, beginning with an open coding approach. This approach was followed by the refinement and regrouping of codes. A coder was involved in the process and worked through continuous iterations with the other researcher to incorporate multiple perspectives and enhance the reliability of the coding. The coding process was applied across multiple data sources, including archives, interviews, and observations. In the first step, we developed a vocabulary, crucial in structuring our understanding of concepts, as derived from the literature, and paired them with examples directly sourced from our data. Through the analysis, we aimed to underscore the connection between theoretical constructs and practical applications observed in the field, highlighting their manifestation in real-world operations within PNALM.

Content analysis and dictionary

The pre-coding phase relates to the development of a dictionary structured following the most relevant concepts identified from the interviews. This phase involved a preliminary analysis in which we highlighted the most frequent keywords from the interviews, seeking connections with the existing literature. According to Creswell (2014), content analysis involves transcribing the thematic content of the interviews by identifying relevant themes within the text. Table 2 presents the emerged dictionary from the pre-coding phase, showcasing the most frequent words identified during the analysis.

In the coding phase, we conducted a comprehensive analysis of the interviews, selecting relevant text segments and assigning them to nodes. These nodes were then divided into sub-nodes based on their content. Twelve variables were identified in accordance with organizational literature and coded into nodes using NVivo software. Our methodological approach followed the guidelines set by Gioia et al. (2013), which emphasizes qualitative data interpretation while maintaining rigorous research standards (Magnani & Gioia, 2023). We defined the key concepts drawn from the literature and identified them in our data as illustrated by direct quotes. We analytically read each part of the interviews, highlighted the most relevant themes, and coded them by assigning them to nodes. We further developed the dictionary by first performing Word Count on NVivo. We extracted

the most frequent words up to a minimum of 8 times. The final list counted 167 words after having cleaned the dataset. Table 7 illustrates the resulting dictionary.

TABLE 7 Dictionary emergent from data: Knowledge, Learning, Tools, and Activities

Concepts	Words
1. Knowledge	
Tacit knowledge	knowledge, experience, skill, behavior
Explicit knowledge	territory, species, position
2. Learning	
Reflexive	recollection, research
Experimental	activity, possibility
Contextual	practice, experience, field
Vicarious	exchange, expert, watching, improvement
3. Communication tools	
Face-to-face interaction	to tell, speak, communicate, voice
Digital interaction	radio, digital, email, call
Analog interaction	card, paper, report
4. Activities	
Monitoring	data, monitoring, information, collection, sheets, observation, analysis, results
Communication and PR	communication, report, news
Scientific research	research, control
Surveillance and services	surveillance, damage, inspection, job
Education and training	education
Priority actions	sighting, report, decision, responsibility
Rapid response actions	problem, complex, luck

The first part of this procedure consisted of identifying relevant raw data from the interviews and categorizing them into first-order concepts and second-order themes, which are more abstract and closer to literature. Raw data reports parts of direct speech

that we coded and aggregated into sub-nodes. Table 8 presents these definitions alongside illustrative excerpts from the interviews.

TABLE 8 Concept definitions and samples: Knowledge Sharing and Learning

Topics	Meaning	Samples from data
Knowledge sharing		
1. Knowledge		
Tacit knowledge	Knowledge that is hard to express, formalize, and share with others, including beliefs, mental models, wisdom, experience, and intuitions.	*'He has his own vocation. I think 30 years' experience in the field. Maybe he knows any movement … maybe a particular sense.' (extract from interview I)*
Explicit knowledge	Knowledge that can be articulated, conceptualized, codified, or stored in formal language and can be easily transferred to others.	*The behaviors, the habits of these animals, i.e., how they use space, what environmental features are associated.' (extract from interview I)*
2. Learning		
Contextual learning	External, exploration-oriented activities performed in the real world or in real-life situations, allowing knowledge to emerge from the environment.	*'A lot of the things we learnt, we learnt with both field information and practical work... So almost everything in the field.'*
Experimental learning	Internal, exploration-oriented activities from which individuals learn based on problem solving, trial and error, simulation, and prototyping.	*'In my first learning activity…, we had to test my stamina to understand the level of my endurance.'*
Reflexive learning	Exploitation-oriented activities from which individuals learn by sharing, analyzing, storing, and using information.	*'We integrated sitting at a workstation in talking about work and observing at the same time.'*
Vicarious learning	Exploitation-oriented activities that allow individuals to gather knowledge from others' experiences in the workplace or from those who have had similar experiences in the past.	*She observed us while we were operating, and she understood how it worked. She then formed herself, i.e., she understood by now how it worked.'*
3. Communication tools		
Face-to-face interactions	All the interactions among individuals occurred directly in person, without the use of any communication tools.	*'We usually go together to the mountains, also with researchers from universities to share our knowledge.'*
Digital interactions	All the interactions among individuals occurred with communication tools based on digital technologies.	*'Internal communication happens through groups and phone calls, so the communication can be continuous.'*
Analog interactions	All the interactions among individuals involving the use of traditional tools for information sharing and coordination.	*'We often prefer to keep requesting papers simply because we then update the databases as needed.'*

4. Activities		
Monitoring	All the activities related to the collection and processing of data to describe, evaluate, and find patterns.	*'Monitoring aims to collect data about animals such as where they are and how many, how many are born... So that we can know what the vital parameters of a population are, …'*
Surveillance and services	All the activities related to the monitoring of the behaviors of wildlife and people to ensuring safe coexistence.	*'Surveillance and control are activities carried out by the park to ensure safety and sensitize…'*
Communication and PR	Activities focused on managing the relationships with locals and interested stakeholders.	*'Communication begins with knowledge: to know in order to communicate, inform, and raise awareness.'*
Scientific research	Ongoing research to deepen understanding of nature, wildlife behaviors, and environmental processes.	*'Research is carried out to understand animal behavior or to address specific research hypotheses.'*
Education and training	Formal and institutionalized activities planned to improve individuals' qualifications, knowledge, or expertise.	*'We used to provide training activities related to field-work tasks, knowledge background, explanation of data collection…'*
High-priority actions	All the activities demanding a coordinated response and attention for critical tasks.	*'The bear is a protected species at national and European levels. It requires special attention in land management by institutions.'*
Rapid response actions	All the activities that require an immediate response to emergency or urgent and unpredictable situations.	*'There are individuals who become confident and occasionally approach urban areas. We tailored specific targeted activities for them.'*

We then developed a visual representation of the analysis, illustrating our data structure, including first-order concepts, second-order themes, and aggregated dimensions. Through content analysis and iterative comparison between our data and the existing literature, we identified the types of knowledge and the forms of learning present in our empirical context. Additionally, we developed a taxonomy of communication tools and activities that reflect the various modes through which interpersonal interactions occur. Finally, we explored the relationships between these concepts in our organizations to understand how interpersonal interactions become a knowledge-sharing mechanism in this dynamic work context. We analyzed the coded data using NVivo software, specifically adopting the Matrix Coding Query feature. This tool enabled us to identify intersections between different items and allowed for the co-occurrence analysis of coded interviews. By employing the co-occurrence analysis, we were able to identify patterns among nodes by counting the frequency of words in sentences that referred to the concepts under study. This analysis revealed the relationship between interpersonal interactions, learning, and knowledge. We framed our results and discussed the findings

in the following sections. Figures 3 and 4 present the resulting data structure emerging from our analysis.

FIGURE 3 Data structure – Knowledge Types and Learning Forms

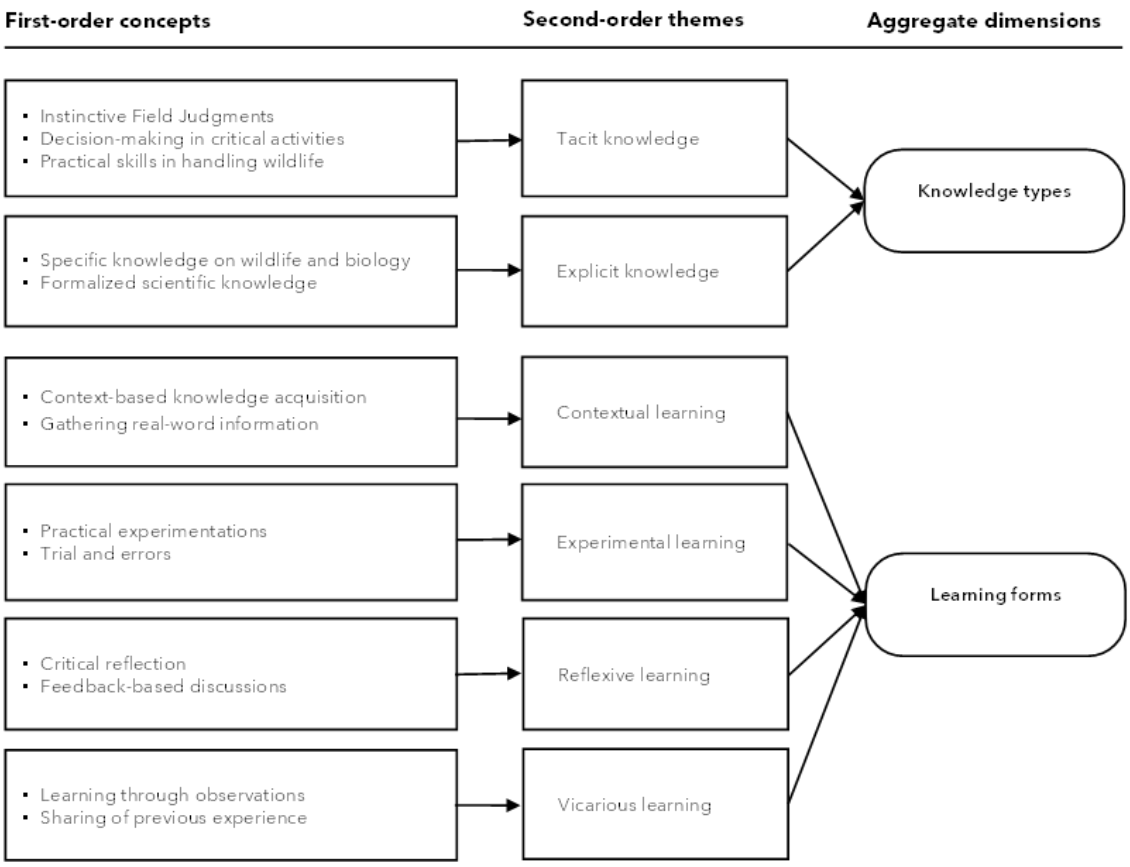
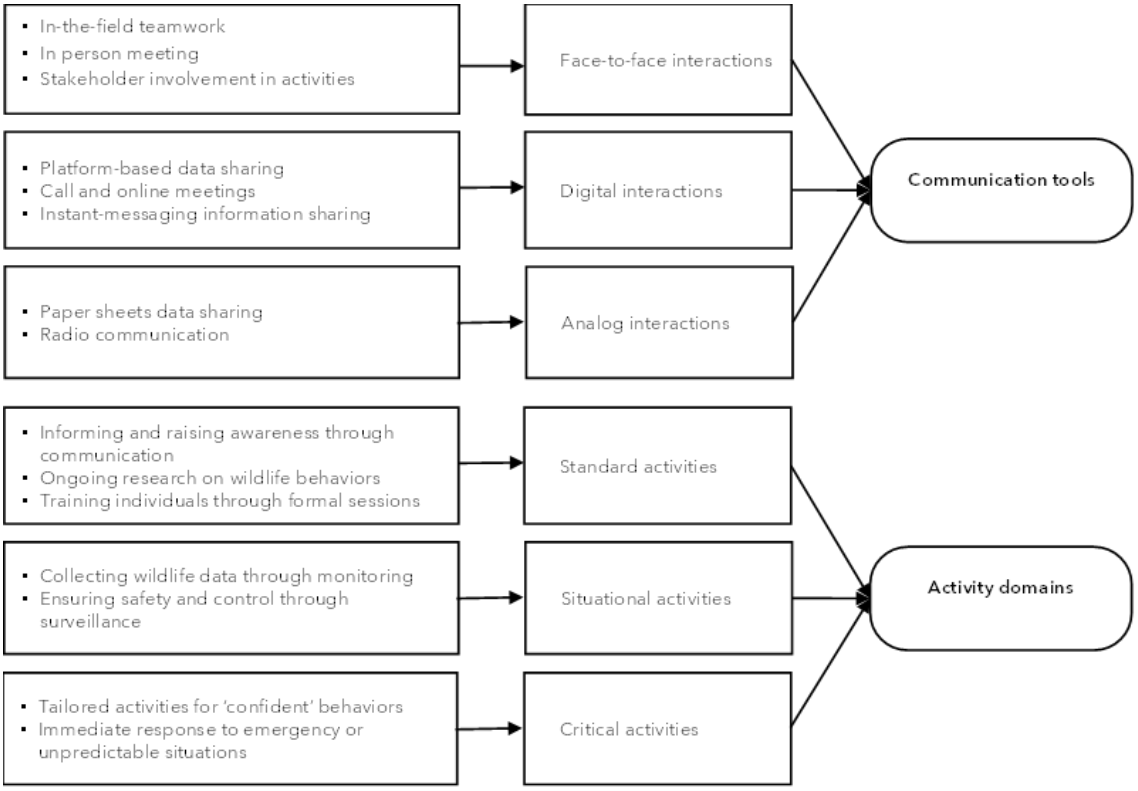


FIGURE 4 Data structure – Interpersonal Interactions: Communication Tools and Activity Domains



Data analysis results

We analyzed interpersonal interactions that occur during various activities and through different communication tools within PNALM and found their role as a knowledge-sharing mechanism.

Interpersonal interactions and learning forms: communication tools

We explored the impact of communication tools in facilitating learning forms in dynamic work contexts. While our results confirm the utility of all types of interactions for learning, they highlight the particular importance of face-to-face interactions in this process, given their higher occurrence. Table 9 illustrates the details of this relationship.

TABLE 9 Matrix Coding Query: Communication Tools and Learning Forms

	Learning form			
Communication tool	**Contextual learning**	**Experimental learning**	**Reflexive learning**	**Vicarious learning**
Face-to-face interactions	897 *(38.32%)*	84 *(3.59%)*	329 *(14.05%)*	**1031** ***(44.04%)***
Digital interactions	48 *(26.09%)*	0 *(0%)*	**127** ***(69.02%)***	9 *(4.89%)*
Analog interactions	0 *(0%)*	**54** ***(61.36%)***	0 *(0%)*	34 *(38.64%)*

More specifically, we observed that when individuals are physically co-located, contextual and vicarious learning are predominant. Conversely, digital interactions are more effective in facilitating reflexive learning, highlighting the importance of communication technology for sharing knowledge. Finally, given the limited occurrence of experiments and trial-and-error processes in our context, experimental learning primarily emerged through face-to-face and analog interactions. These results highlight the ongoing relevance of traditional methods of communication alongside modern ones, even in contexts that are increasingly supported by digital technologies.

Interpersonal interactions and learning forms: activity domains

We aggregated the multitude of activities that were conducted in our context and classified them into three macro categories: standard, situational, and critical activities. Standard activities refer to regularly well-established tasks carried out, such as routines or procedures. They include research activities, communication and public relationships, and education programs. Situational activities relate to context-specific tasks that can vary depending on circumstances, requiring an adaptive response. They involve monitoring and data management, surveillance, and services within the field. Critical activities involve urgent and high-stakes tasks that demand immediate action and coordination, including emergency or unexpected events. These activities are defined by their high priority or the need for a rapid response. All these activities represent opportunities for rich and meaningful interpersonal interactions, requiring mutual understanding, a strong commitment to working in groups, and a willingness to share knowledge, thereby becoming powerful channels for learning. Table 10 below illustrates how learning unfolds within these activities.

TABLE 10 Matrix Coding Query: Interactions and Learning Forms

	Learning form			
Activity domain	**Contextual learning**	**Experimental learning**	**Reflexive learning**	**Vicarious learning**
Standard activities	116 *(22.70%)*	18 *(3.52%)*	**313** ***(61.25%)***	64 *(12.52%)*
Situational activities	**668** ***(39.25%)***	253 *(14.86%)*	127 *(7.46%)*	654 *(38.43%)*
Critical activities	89 *(42.38%)*	0 *(0%)*	0 *(0%)*	**121** ***(57.62%)***

Our results suggest that interpersonal interactions during standard activities play a key role in facilitating reflexive learning, while interactions occurring during situational activities primarily support contextual learning, more than the other forms. Lastly, interactions in critical activities, characterized by their urgency and unpredictability, and mostly led by the most experienced personnel, serve as the main facilitators of vicarious learning.

The role of learning in shaping knowledge

We underscore how the different forms of learning, respectively contextual, experimental, reflexive, and vicarious, shape and enact both tacit and explicit knowledge. Table 11 below illustrates this relationship.

TABLE 11 Matrix Coding Query: Learning Forms and Knowledge Types

	Knowledge type	
Learning form	**Explicit knowledge**	**Tacit knowledge**
Contextual learning	**590** *(64.69%)*	322 *(35.31%)*
Experimental learning	**48** *(64.86%)*	26 *(35.14%)*
Reflexive learning	**292** *(77.25%)*	86 *(22.75%)*
Vicarious learning	362 *(27.7%)*	**945** *(72.3%)*

First, through the co-occurrence analysis, we found, unsurprisingly, that reflexive learning is more effective in driving explicit knowledge as well as contextual learning, which resulted in the strongest driver of explicit knowledge. Second, we found that experimental learning, where action precedes cognition, is the most balanced form of learning, shaping both explicit and tacit knowledge. Finally, vicarious learning emerged as the most effective form for conducting tacit knowledge, allowing individuals to assimilate unspoken know-how and understanding from the direct experience of others.

Findings and discussion

Through our exploration of wildlife operators of varying levels of expertise dealing with a dynamic work context, we investigated the role of their interpersonal interactions. We developed a model that illustrates how knowledge-sharing mechanisms unfold across diverse activity domains and through different communication tools, ultimately shaping knowledge. Following, we discuss our findings and support our arguments by directly comparing the perspectives of experienced individuals (referred to as *mentors*) and those of trainee individuals (referred to as *learners*) using selected extracts from interviews conducted with both groups.

To begin with, we analyzed the role of interpersonal interactions occurring through communication tools – face-to-face, digital, and analog interactions – and within activity domains – standard, situational, and critical activities – in relation to learning forms (Bosua & Scheepers, 2007; Bresman & Zellmer-Bruhn, 2013; Edmondson, 2002; Harvey, Bresman, & Edmondson, 2018; Kane & Alavi, 2007; Michailova & Sidorova, 2011; Seely & Duguid, 1991).

Our results highlight the paramount importance of face-to-face interactions for contextual and, more prominently, vicarious learning. These insights contribute to the ongoing debate on the importance of collective interpretation and the co-construction of meaning through dialogue and shared experience (Argote & Miron-Spektor, 1999; Myers, 2018, 2021). As two interviewees stated: "*Much of the work that is done is then done 'live', in the sense that people come with us in the field and then learning occurs directly hands-on.*" – *"At that point, you provide the newcomers with experiences, such as "you can*

come with me to monitor the bears and set up a camera trap" (extract from mentors' interviews). Complementing this, the perspective of the trainee supported the importance of learning through experience and in-person conversations: "*99% of the things we have learned have been through hands-on field experience, as well as through the practical advice of our colleagues daily." (extract from learner's interview).* Both contextual and vicarious learning are evident in these extracts. By inferring additional meaning from the context, trainee gain insights not only through their direct experiences in the field, but also from the experiences of others, being directly involved.

While both of these learning forms are facilitated by face-to-face interactions, our findings suggest that different activity domains foster each of them. We found major occurrences of contextual learning within situational activities, where teams are involved in conducting real-time field operations: "*There is a time for conferences or lectures, let's call them that, other times through direct experience in the field, let's say…" (extract from mentor's interview).* Our findings suggest that trainees regard practical experiences as the principal source of knowledge, particularly when it comes to information 'not covered in books': "*there are many things you may not read in books, but that in practical experience you can learn from any source." – "The main part of our learning occurred through field practice, directly with practical experience." (extract from learners' interviews).*

Despite moderate occurrence of situational activities in facilitating vicarious learning, our findings highlight the prominence of critical activities fostering learning "through the experience of the others. This is evident in the following excerpt from the story of rapid response action: "y*ou're working, then a particular situation happens, and you have to confront that immediately... at that moment there's no time to explain it beforehand, but directly on the spot... she was with us and observed!" (extract from mentor's interviews).*

This finding draws attention to research on vicarious learning in organizations by emphasizing how the 'raw' experience can shape novel insights and knowledge in the work context (Michailova & Sidorova, 2011; Myers, 2022; Posen & Chen, 2013).

On the other hand, we found that reflective learning is primarily facilitated by digital interactions and standard activities within office settings, such as data analysis for research or communication tasks. As one interviewee noted: *While having a background in a particular field is valuable, we have also incorporated the practice of discussing and*

observing our work while being 'stationary' [in the office]. – 'Through the analysis of our data… we revised some of our knowledge. We found that bears cross through ten valleys. We analyzed the kilometers travelled by the last bears sampled.' (extract from mentors' interviews). Our findings demonstrate the importance of discussing, analyzing, and revising previous activities, processes, and beliefs. Surprisingly, we found major occurrences of digital interactions facilitating these 'organizational introspection' activities, thereby supporting continuous refinement or improvement of internal processes: "y*ou always need the cooperation of other park rangers, so exchanging information on an ongoing basis is a good form of collaboration and learning." (extract from mentor's interview).* Consistent with our results, digital interactions facilitate reflexive learning through communication tools and information-sharing processes. This happens particularly when organizational units are spread over large distances.

Finally, our findings suggest that analog interactions contribute to the overall picture, as we observed minor co-occurrences with experimental learning. For instance, in our context, they initiated an internal communication initiative to share knowledge and news across the organizational unit: *"we experimented with a sort of internal journal, where all the relevant information were shared among all members…" (extract from mentor's interview).*

Next, we analyzed how the four learning forms – contextual, reflexive, experimental, and vicarious learning – shape explicit and tacit knowledge (Bosua & Scheepers, 2007; Cabrera & Cabrera, 2002; Duguid, 2005; Nonaka & Takeuchi, 1995). Our results highlight that explicit knowledge, which can be easily expressed, is primarily shaped by experimental and reflective learning. Additionally, contextual learning also plays a significant role in conveying explicit, codified knowledge, which is articulated and shared through interactions within the activities. As this excerpt from an interview highlights: "*There are some lessons in the field, which means that when you arrive, you are explained where to look, what to look at, for example, to distinguish specific species of animals or to understand their age…" (extract from mentor's interview).* The trainees were able to easily articulate what they had learned in the field. For instance, they learned to recognize species, their behaviors and habits, mastered the use of technologies, and developed expertise in surveillance and data collection activities. This knowledge type, rooted in

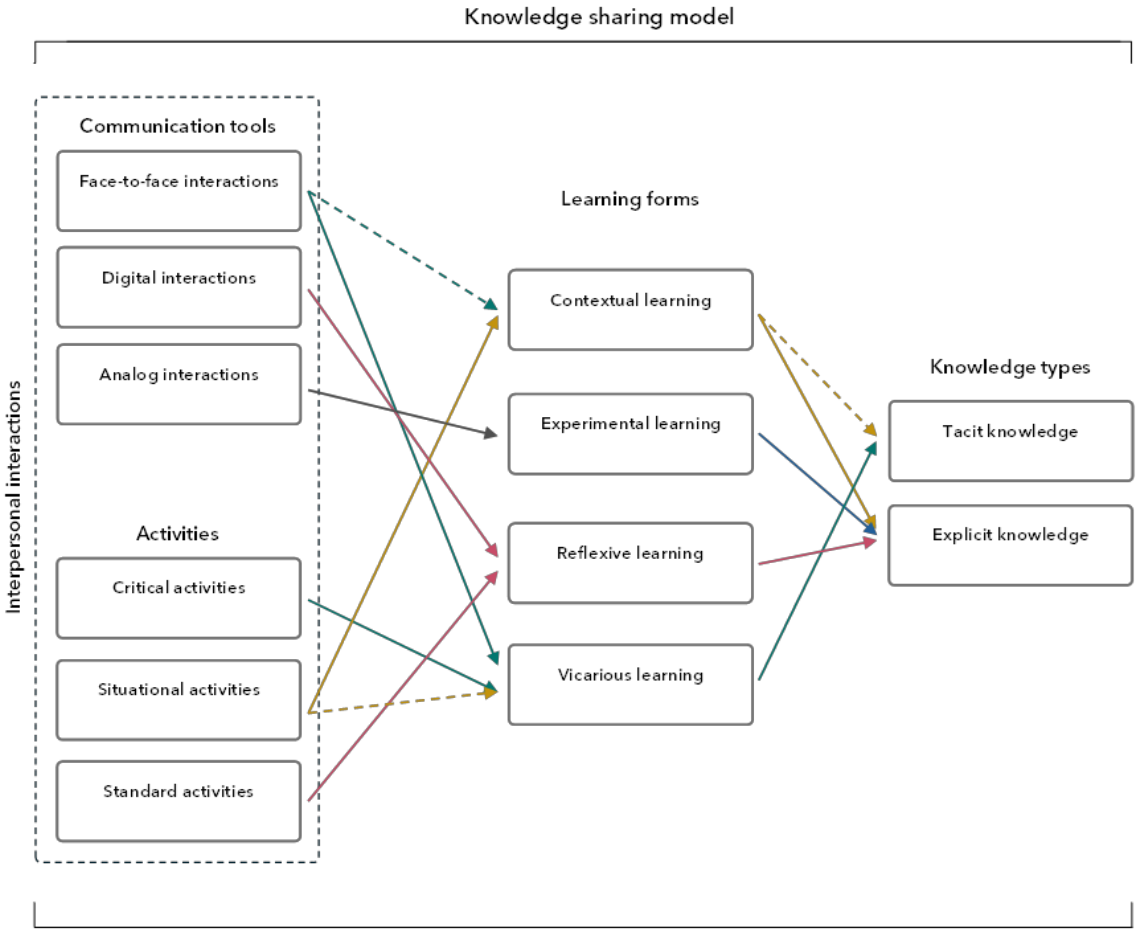
'*knowing that*' (Brown & Duguid, 2001), is indeed characterized by its ability to be easily articulated and shared, making it a clear example of explicit knowledge.

Finally, our most significant finding offers crucial insights into the relationship between vicarious learning and types of knowledge. We provide evidence that vicarious learning is highly effective in shaping tacit knowledge. Below are excerpts illustrating its crucial role in the relationship: '*She was observing: "Now, this is how it's done, how to approach people, how to conduct inspections...". She was really good at it… She realized that she had to watch. She quickly learnt." – "She watched us while we operated, she understood how it worked. She molded herself then… I mean, she understood by now how it worked, but without us saying." (extract from mentors' interviews).* The following are further examples of vicarious learning: *'it worked that, well, they worked alongside us… We were doing things, they stood by us, they were observing... It's very personal and subjective; it also depends on who you're with in the territory you're going to work in, even your own approach." (extract from mentor's interview)*. Adding to that: "*he taught us all, from the way he arrived in the morning, how to wear the uniform, he was an example that we still carry on"* and finally: *"the objective was to transfer your values and also your professionalism." (extract from mentor's interview, reminding her first experience).*

Subsequently, we found alignment with the trainees' opinions regarding vocations, intuitions, approaches to work, expertise, and know-how, from which we can observe how tacit knowledge takes shape and is shared: "*I collaborated with the most experienced park ranger. I learned practically from him, and I still have a lot to learn… Let's say that the training took place in the field, and this is the right way. However, I consider myself very lucky… He is highly experienced with bears. He has a vocation all of his own. I think 30 years of experience in the field. He probably knows any movement of any bear; he understands it first." (extract from learner's interview).* Our findings highlight how vicarious learning, learning through the direct experience of others, involves sharing tacit elements of a prior experience, in addition to the sharing of concrete, but hard-to-articulate knowledge. To conclude, a final remark on tacit knowledge from a mentor's interview follows: *"... referring to the interpretation of the service [talking about values] … It follows specific perspectives and views…" (extract from mentor's interview).*

Figure 5 shows the results of our analysis by illustrating how knowledge sharing unfolds through interpersonal relationships, learning forms, and knowledge types. The shapes and colors of the arrows are used to visually represent and clarify the paths of these relationships.

FIGURE 5 Knowledge Sharing Process in dynamic work contexts



Conclusions

With this research, we aimed to explore the role of interpersonal interactions in enabling knowledge sharing within dynamic work contexts as knowledge-intensive sectors, emergency healthcare services, or grand challenges settings (Gehman et al., 2022; George et al., 2016; Maanen & Kolb, 1982; Muniz et al., 2024; Myers, 2022). Our results are based on content analysis of rich, detailed, qualitative data from PNALM, an organization involved in environmental safeguarding initiatives. We addressed the role of interpersonal interactions in facilitating learning forms by analyzing them from two perspectives: the

communication tools mediating the relationships and the activities in which these interactions occur. First, we demonstrated the importance of face-to-face, digital, and analog interactions within activity domains in supporting contextual, experimental, reflexive, and vicarious learning and illustrated how these relationships unfold. Second, we investigated how these forms of learning shape tacit and explicit knowledge. These insights complement existing studies on knowledge sharing by detailing the relationships among interpersonal interactions, learning forms, and knowledge exchange (Elias & Farah, 2020; Liang & Suntrayuth, 2024; Muniz et al., 2024; Nakano et al., 2013; Smith, 2001; Venkitachalam & Busch, 2012).

While providing a detailed view of knowledge sharing mechanisms in dynamic work contexts, our study presents some limitations. This research is based on a single case study, which may limit the generalizability of findings. To enhance the applicability of the results, we suggest that future research replicate this study in other complex 'grand challenges' contexts. We further suggest that future explorations may develop a multiple case study, as this would increase the reliability of results by identifying more consistent patterns (Yin, 2003). Additionally, we recommend further research to investigate each learning form in-depth, as more insights could be gained through a more detailed analysis.

When it comes to modern dynamic work contexts, such as environmental safeguarding initiatives, where work is ambiguous and difficult to observe or train for, effective knowledge-sharing mechanisms assume paramount importance. These demands require even more careful adaptation, appropriate tools, and the required level of information detail for specific situations. In such contexts, interpersonal interactions play a crucial role in facilitating learning and disseminating both tacit and explicit knowledge through informal processes. Understanding how this process occurs and identifying the factors that facilitate it will allow organizations to better leverage their collective expertise, fostering continuous learning and sustaining more effective knowledge management.

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5. Paper II: Configuring the Data Value Chain for Grand Challenges: Actors and Dimensions of Data Governance [2]

Paper II is a qualitative exploration of data governance aspects in grand challenge contexts, where data-driven technologies represent both opportunities and sources of complexity. Based on PNALM and its close stakeholders, the study illustrates how organizations configure the Data Value Chain (DVC) by orchestrating actors, resources, operations, and data flows across extensive territories. The paper demonstrates how physical, digital, and organizational dimensions of the DVC interact to enable multi-actor coordination, effective data governance, and value extraction from heterogeneous and dispersed data. It highlights the importance of integrated, multi-dimensional, and collaborative approaches to data governance in these contexts.

This paper is written in collaboration with Prof. Federica Ceci from the G. d'Annunzio University.

This paper has been submitted to the *Communications of the Association for Information Systems* Journal and is currently under the first round of review.

[2] Paper written in collaboration with Federica Ceci – G.d'Annunzio University

Abstract

Organizations addressing grand challenges (GCs) operate in contexts that require coordinated action across multiple stakeholders. In these settings, data are essential to enable collaboration and evidence-informed decision-making, yet they often originate from heterogeneous, dispersed, and boundary-spanning sources across both physical and digital environments, increasing the complexity of data governance and integration. Drawing on observational data, interviews, and archival documents from the National Park of Abruzzo, Lazio, and Molise (PNALM), this study examines how organizations configure the Data Value Chain (DVC) to manage multi-source, distributed data, essential to support environmental and wildlife conservation strategies. We frame the DVC as an integrated, multi-dimensional system, where physical, digital, and organizational dimensions interact and co-evolve, and show how their configuration shapes data governance in complex GC settings. This study provides guidance for organizations tackling GCs by outlining how to configure and govern the DVC across its interdependent physical, digital, and organizational dimensions, enabling multi-actor coordination and value extraction from highly heterogeneous and dispersed data within complex data ecosystems.

Keywords: data value chain, data governance, collaboration, challenges

Introduction

Grand challenges (GCs) are large-scale societal problems that require coordinated action across multiple stakeholders and distributed solutions. In such contexts, data become central to enabling collaboration, evidence-informed decision-making, and accountability across organizational boundaries. At the same time, today's rapidly evolving technological landscape, driven by advances in IoT, sensors, cloud computing, and connectivity, has expanded the volume and heterogeneity of available data, with a growing share generated across both digital and physical domains. While these developments create new opportunities for organizations to collaborate, share resources, and thrive in an increasingly interconnected organizational environment, they also introduce significant challenges (Kapoor & Teece, 2021; Kraus et al., 2021). Although prior research highlights that extracting value from data requires managing a sequence of interdependent activities, conceptualized by the Data Value Chain (DVC) framework, the literature does not adequately address the inherent complexity of GC contexts. In these settings, multi-actor collaboration and distributed activities across field and digital infrastructures generate intricate data flows that span organizational boundaries and involve diverse actors and data sources. Consequently, new questions arise regarding how data should be governed, and by whom, to ensure the extraction of value while avoiding undesirable outcomes.

Understanding how the DVC can be configured and governed in boundary-spanning settings becomes critical, especially when data are generated in dispersed, heterogeneous, and field-based conditions typical of GCs. GC contexts amplify the complexity and challenges of data governance, management, and integration because of their large volumes and heterogeneous, dispersed, and even hard-to-access sources (Akter et al., 2024). Management scholars highlight that GCs are large-scale problems, ranging from poverty alleviation to environmental protection, that require collaborative efforts and local-scale, distributed solutions (Angeli et al., 2022; Davidson et al., 2023). Addressing GCs requires multiple actors, distributed experimentations, and a common approach (Angeli et al., 2022; Davidson et al., 2023; George et al., 2016). In such situations, data governance becomes a multi-actor process, involving interdependencies among organizational units, external partners, and technological systems, whose interactions require particular attention across the DVC (Åkerman et al., 2018; Akter et al., 2024).

The DVC is inherently socio-technical: its activities unfold across digital infrastructures and physical settings (Åkerman et al., 2018; Marchesani, 2023; Schreiber & Metternich, 2022; Urbano et al., 2024; Zhang et al., 2013). This dual occurrence creates an additional layer of complexity, as physical and digital activities are fundamentally different in nature, requiring distinct management approaches, resources, and technological integration. The interplay between these environments necessitates coordination to ensure seamless operations and optimize performance across the DVC. Secondly, these dependencies must be managed continuously through all the DVC, particularly in GC contexts characterized by multiple actors. Consequently, this study aims to advance our understanding of data governance by examining how organizations operating in GC contexts configure the DVC to integrate heterogeneous and dispersed data sources, technologies, and actors, and to manage the additional complexity inherent in these settings.

To advance understanding of data governance in GC contexts, we conducted an in-depth case study in an environmental safeguarding initiative. We investigated how a leading environmental organization manages data in a context where multiple organizational units and external partners collaborate to advance environmental safeguarding through a data-based approach. Our study focuses on the National Park of Abruzzo, Lazio, and Molise (Parco Nazionale di Abruzzo, Lazio e Molise - PNALM), an organization in the Central Apennines dedicated to preserving wildlife and natural landscape. PNALM employs various strategies to ensure the coexistence between humans and wildlife, including data-related operations such as wildlife monitoring, censuses, and scientific research. These operations require widespread use of technologies and close collaboration among multiple organizational units and external partner organizations. This case is particularly compelling as PNALM operates in a "GC context" and must overcome significant data governance challenges due to the inherent complexity of the DVC configuration in such settings(Angeli et al., 2022; Davidson et al., 2023). A highly integrated DVC, robust use of data technologies, and seamless coordination are required to identify patterns, develop real-time solutions, and support data-driven decision-making in multi-actor settings (Åkerman et al., 2018; Akter et al., 2024). Therefore, the research question that underpins this study is: *How do organizations govern and coordinate the data value chain (DVC)*

in grand challenge (GC) contexts characterized by heterogeneous, dispersed, and boundary-spanning data?

To answer the questions, we draw on qualitative data including open-ended interviews, participatory observations, and archival documents. The remaining of the paper is structured as follows: first, we introduce DVC and data governance literature to provide the background of the study. In the subsequent section, we present the methodology, including the description of the context, data collection, and analysis. Finally, we summarize our contribution and identify future research directions.

Theoretical Background

Data Value Chain (DVC)

The adoption of data-driven technologies as strategic assets prompts organizations to experience transformation across multiple dimensions (Curry, 2016; M. E. Porter & Heppelmann, 2015; Redman, 2008). These transformations include the digitization of traditional infrastructures (Curry & Ojo, 2020), changes in management strategies (Constantiou & Kallinikos, 2015; Curry, 2016), and adjustments in decision-making processes (Brynjolfsson & McElheran, 2016; Provost & Fawcett, 2013). However, their impact is not immediate. In order to generate a shift in practices, data must gain value through multiple steps in their path from acquisition to utilization (Curry, 2016; Rayport & Sviokla, 1995). Understanding these steps is crucial to recognizing the path through which value can be extracted from data. They are part of the DVC model developed by Curry (2022). The DVC is a framework that illustrates how the flow of data creates value across a series of steps: acquisition, analysis, curation, storage, and usage (Curry, 2016). The DVC describes the entire path of data from their initial acquisition to their final usage (Curry, 2016; Watch, 2017). Curry described each step of the DVC as follows:

- **Data acquisition**, the process involved in collecting, checking, and organizing data before it is stored in a database or other infrastructure.
- **Data analysis**, the processes that prepare data for domain-specific use, include exploring and highlighting relevant data or revealing meaningful, hidden information.
- **Data curation**, the active management of data throughout its lifecycle to ensure quality and reliability for effective use.

- **Data storage,** the preservation of data to ensure it remains available for access and reuse in a scalable manner.
- **Data usage,** the effective exploitation of data to enable operational and strategic value creation.

FIGURE 6 Data Value Chain Model from Curry (2016)

Designed to analyze activities related to data and technologies within organizational settings, the DVC represents a central element of the future knowledge economy due to the opportunities it provides for the digital advancement of economic sectors (Curry & Ojo, 2020; DG Connect, 2013). Despite the potential of data to help organizations address GC, governance issues, such as data sources, legitimate uses, the data lifecycle, interoperability, and coordination across actors, remain critical and largely unresolved (Nambisan & George, 2024). In the following sections, we examine the role of coordination and collaboration alongside their implications for data governance, highlighting emerging dimensions and challenges that organizations must navigate to leverage data effectively in complex, multi-actor contexts.

Managing actors across the DVC in response to GCs

Scholars in management and information systems domains emphasize the need for research focused on finding solutions to GCs (Davidson et al., 2023; George et al., 2016; Nambisan & George, 2024). There is widespread agreement that the high volume of data organizations handle through digital technologies could contribute to tackling GC and improve societal well-being (Davidson et al., 2023; Faik et al., 2020; Ncube et al., 2023). However, new questions related to data governance are emerging, particularly regarding the scope and configuration of data collection, interpretation, sharing, and use (Abraham et al., 2019; Davidson et al., 2023; Faik et al., 2020). Given the dispersed nature of data and the need to manage the increasing complexity of addressing GCs, identifying key challenges related to the DVC becomes essential.

A central aspect of addressing GCs is that advancing solutions requires collaborative actors and partnerships who commit to a shared purpose (Ferraro et al., 2015; George et al., 2016). This need for collaboration intensifies through the widespread datafication of organizational processes, as more data can improve understanding, coordination, and responsiveness to GCs (Davidson et al., 2023; Rayport & Sviokla, 1995; Susha et al., 2023). For organizations to benefit from these data, they must be willing to engage in multiple forms of collaboration, making continuous data sharing practices a core mechanism of these relationships. While the DVC provides a framework for structuring and managing data-related processes, GC contexts require seamless alignment and interaction across internal and external actors, including functional teams, data managers, partners, suppliers, and public stakeholders. Consequently, managing actors becomes crucial, as organizations must align and configure distinct roles, responsibilities, and interactions to effectively generate value from data. This makes the coordination of socio-activities a central aspect of DVC configuration in GC settings.

GCs and the emerging dimensions in building the DVC

Despite the considerable potential of data to drive advancements in solutions for GCs, a range of technical and organizational challenges continues to affect activities, operations, and decision-making processes (Curry, 2016; McAfee & Brynjolfsson, 2012). This requires a nuanced understanding of how data-related activities and actors interact across the DVC. The literature has extensively examined the challenges associated with adopting or using data-related technologies, as well as their impact on organizational settings and human action across various sectors (Åkerman et al., 2018; Cavanillas et al., 2016; Faroukhi et al., 2020; Frias-Martinez et al., 2012; Hernández-Moral et al., 2021; Kilgus et al., 2024). In GC contexts, human activity and advanced technologies shape the data governance process. This intersection of digital, organizational, and physical elements introduces a unique configuration challenge not fully captured by traditional DVC models. Existing research often treats DVC stages as isolated or sequential, rather than examining how they are interdependent in complex, real-world environments. To address this gap, we identify three emerging and interconnected DVC dimensions that the literature has thus far considered individually.

Digital dimension

The digital dimension focuses on challenges related to the technical infrastructure enabling data collection, standardization, storage, and interoperability. A key aspect regards the "virtualization" of data, which involves transforming information from physical to digital environments. Digitization standardizes data from diverse sources such as analog technologies into digital formats (Leonardi & Treem, 2020), while "datafication" extends this transformation by converting more aspects of human and social activity into data that can be used to create new sources of value (Cukier & Mayer-Schoenberger, 2013). These processes significantly expand the volume and heterogeneity of data, prompting organizations to reconsider their collection, analytics, and decision-making processes (Leonardi & Treem, 2020).

Digital-related challenges include issues such as interoperability, data quality, data infrastructure, and data-enabling technologies. While these challenges are relevant for data-related processes in general, they become particularly pronounced in GC contexts, where partners come from diverse fields, possess varying levels of expertise, and operate across heterogeneous organizational and technological environments. For example, prior studies have explored the adoption of smart technologies such as IoTs and investigated the data-related challenges associated with this implementation in various sectors such as agri-food, farming, and manufacturing (Åkerman et al., 2018; Clarysse et al., 2022; Martens et al., 2022). However, within these processes, the boundaries defined by data-related technologies often do not align with the actual organizational workflows. Beyond technological capabilities, human agency remains essential for value creation, enabling access to diverse data sources and facilitating the transition from information from the physical to the digital environments through both human activities and human–machine interactions (Someh et al., 2019; Wirén et al., 2019).

Organizational dimension

The organizational dimension captures how actors, both internal and external, coordinate, govern, and execute data-related activities. Internal actors, such as data managers, analysts, and functional teams, play a central role in operationalizing processes, while external partners, such as suppliers and stakeholders, contribute additional data, expertise, and capabilities. In GC contexts, these relationships demand mechanisms for

coordination, knowledge sharing, and alignment of interests. In such contexts, the organizational dimension becomes particularly critical as the diversity of actors, objectives, and expertise requires robust orchestration strategies (Nambisan & George, 2024). These strategies are required to define clear roles and design mechanisms for collaboration and knowledge sharing (Davidson et al., 2023). Managing these socio-technical relationships is therefore essential for overcoming the complexity of data integration and maximizing value extraction across the DVC.

Organizational challenges typically arise when actors have differing priorities or operate under distinct routines, governance rules, and expectations for data use. For example, instance, research has investigated the challenges of transforming various sectors through data analytics and highlighted the emerging organizational and coordination challenges of working with multiple teams and heterogeneous technologies (Basile et al., 2024; Dal Mas et al., 2023; Festila & Müller, 2022). These challenges intensify in GC settings, where organizations often operate with extensive off-site activities, rely on diverse technologies, and manage dispersed data sources. Effective coordination is essential to support an increasingly integrated DVC, which depends on advanced technologies such as IoT devices and cloud platforms to identify patterns, enable real-time decision-making, and generate societal value (Akter et al., 2024b). The complexity of these settings has implications at both individual and organizational levels, shaping privacy concerns, decision processes, and governance practices (Someh et al., 2019).

Physical dimension

The physical dimension highlights the origin of data in real-world settings, where data are often unstructured, heterogeneous, and dependent on human activity for capture and interpretation. These data are often unstructured, heterogeneous, and dependent on human activity for collection, processing, and interpretation (Cavanillas et al., 2016). Organizations operating in sectors with substantial field operations must integrate these physical sources with digital systems, requiring coordinated DVC, advanced technologies, and seamless human-technology interaction capabilities (Akter et al., 2024). The challenges of managing such distributed data sources have implications at multiple levels, from individual to organizational decision-making.

Data sources of different natures generate distinct types of data that must be acknowledged, captured, standardized, and stored to maximize their utility (Cavanillas et al., 2016). Even though technical solutions designed to acquire data from different sources must accommodate a wide range of different implementations, not all data originate from technological tools. As human agency plays an essential complementary role in this process, organizations handle vast amounts of unstructured data alongside structured data. The significant presence of off-site operations makes data-related activities occur in the physical settings, alongside the digital dimension (Åkerman et al., 2018; Akter et al., 2024). Consequently, in such settings, data are generated from a diverse array of sources, requiring various steps to enable their virtualization to unlock their value (Cavanillas et al., 2016; Wirén et al., 2019).

Although literature has examined the configuration of the DVC in multiple sectors and highlighted several sector-specific challenges (Curry, 2016; Hernández-Moral et al., 2021; Wirén et al., 2019), it is only recently that they have begun investigating their implications in addressing GCs (Corbett et al., 2023; Kilgus et al., 2024; Ncube et al., 2023). Ranging from combating poverty and facing climate change to safeguarding the environment, such as reversing biodiversity loss, GCs represent extreme cases where capturing and integrating physical and digital data becomes crucial (Angeli et al., 2022; George et al., 2016). Due to their complexity, involving multiple actors and frequent off-site operations, these contexts present novel challenges that are more difficult to overcome than traditional sectors. In these settings, human agency and technology must work together to ensure data are captured, shared, and processed to generate meaningful societal value.

The three emergent dimensions from the literature, digital, organizational, and physical, represent our elaboration of the theoretical foundation of the DVC within GC contexts and constitute the conceptual background we adopt to analyze how the DVC is configured. In the methodology section, we operationalize them into three analytical dimensions and develop the relative implications.

Methodology

Empirical context

Our empirical context is represented by the Parco Nazionale d'Abruzzo, Lazio e Molise (PNALM). Founded on the 9th of September 1922, PNALM is the oldest national park in Italy and one of the richest in biodiversity. It is home to endemic species, including the iconic Marsican bear and the Apennine chamois, along with other notable species such as the Apennine wolf, deer, and golden eagle. Over the years, PNALM has committed to protecting the environment in its untamed original state while promoting conservation and fostering the sustainable management of natural resources. The organization integrates environmental and cultural initiatives, territorial promotion, stakeholder engagement, and sustainable experiential tourism, all while maintaining a deep respect for nature. Guided by the principle that '*to protect, you need to know*,' the Park is dedicated to preserving nature and biodiversity through the implementation of extensive research plans aimed at deepening the understanding of the territory's historical, social, geological, faunal, and vegetational aspects. These efforts take concrete expression through the work of several organizational units, including technical, surveillance, and scientific domains. These units work together on a range of activities, including monitoring and surveillance, conducting in-depth research, collaborating in innovative projects with key stakeholders, and promoting initiatives aimed at raising awareness and encouraging positive coexistence between humans and wildlife. These activities are conducted throughout the vast territory and are supported by a wide range of data technologies that enable the collection, sharing, management, and effective use of data.

Safeguarding the natural environment is a significant challenge, as it is essential to the ecological, recreational, cultural, economic, and scientific dimensions of human life. Extensive data collection enables organizations to better understand and manage critical phenomena such as climate change, biodiversity loss, ecosystem modifications, territorial health, and air quality. More broadly, there is widespread consensus that the vast amounts of data organizations handle can play a crucial role in addressing grand challenges and enhancing societal well-being. Despite these opportunities, data management challenges in these contexts are significant. In the present paper, we examine the organizational efforts of PNALM, with a focus on the managerial challenges that arise as the

organization engages in the grand challenge of environmental safeguarding. To fulfill its mission, PNALM conducts its activities, it must rely on both traditional and digital tools for data management to enable ongoing improvement of knowledge, inform decision-making, and increase operational effectiveness. Examples of such activities include monitoring activities, involving systematic data collection and analysis to evaluate population trends; simultaneous counts, organizational arrangements to observe and collect insights by multiple sources; wildlife censuses, processes used to estimate the distribution of wildlife populations; surveillance and inspection, consisting of continuous monitoring of wildlife, habitats, or specific environmental conditions.

One of the main activities carried out is monitoring. While conducting monitoring activities, a multi-layered data collection approach is employed, which is essential for evaluating the conservation and health status of a wildlife species. First, monitoring teams are organized to go into the field, in synergy, and collect observational data to count, track movements, and assess the species' health. Second, they utilize IoT technologies such as radio collars to collect GPS tracks of animal groups. These technologies support the teams in locating wildlife as well as gathering more specific and accurate information, thereby enriching the data collection and creating an additional source of data. This two-way data stream must be managed along the DVC to prevent duplication and maintain data integrity. Data must be standardized, stored, and shared with stakeholders, including research organizations, public institutions, or other partners engaged in projects who will need access to these data. Another example of a key activity undertaken by the organization involves research studies, which require extensive data collection and proper data management. Through this activity, PNALM aims to gain a comprehensive understanding of population trends or specific wildlife phenomena, thereby improving conservation strategies. Research studies are often conducted in collaboration with public and private organizations, including universities, NGOs, and other research institutions. These studies rely on extensive use of data-related technologies and processes such as data analysis, sharing, storage, and evaluation. Data for research are collected in various, heterogeneous forms: digitally through technological tools, traditionally, using conventional methods and tools, and as physical samples. These various formats must be gathered off-site from the field, either through technologies or with the direct involvement of team members and collaborators working beyond the organizational boundaries.

Subsequently, the data must be integrated, processed, and analyzed to derive meaningful insights.

PNALM configured a DVC that is designed to facilitate flexible data management, enabling effective data sharing both across the organizational units and with external stakeholders. Internally, it connects all organizational areas, facilitating collaboration for their shared mission. Externally, it draws in other actors, such as NGOs and universities, who are involved in shared environmental purposes. Indeed, PNALM conducts various data-related activities that, depending on the purpose and the skills required, particularly for data analysis, lead to several collaborative agreements to outsource certain operations to achieve broader objectives or conduct more advanced analysis. Data sharing beyond organizational boundaries introduces additional challenges related to collaboration, such as task coordination among partners, the methods of data sharing, and the technological implications involved.

DVC and digital technologies in PNALM

Within the organization, all units, including technical, surveillance, and scientific domains, collaborate toward the shared goal of environmental safeguarding. PNALM has configured its DVC to effectively monitor wildlife population trends over time, tracking behaviors, births, key areas, and biological data. These data serve multiple purposes, including supporting research, informing decision-making, enhancing organizational knowledge, and fostering educational initiatives to improve human-wildlife coexistence.

Data collected from field operations are gathered and analyzed, with both traditional and digital technologies, and both play essential roles in these processes. For instance, technologies such as radio collars, mobile apps, and databases, along with traditional and digital communication tools, are regularly employed to facilitate data-related operations. A typical scenario involves multiple teams working together to monitor specific wildlife. This process requires careful planning, organization, and coordination among the teams as they physically move through the mountains in search of target wildlife. The teams must carefully coordinate to avoid overlapping efforts while ensuring comprehensive coverage of the entire study area. The region is characterized by a natural and untamed landscape, lacking roads or established pathways. Field operations require navigation through challenging terrain, including forests, rocky outcrops, and cliffs, often while

carrying specialized equipment essential for data collection and monitoring. Geolocation technologies, such as radio collars and mobile apps, are used to track animal movements, complemented by traditional methods of data collection. In addition, during the data collection, teams must maintain continuous communication and regularly update each other on their findings. They must share real-time updates to prevent duplication and ensure the efficient gathering of information. All the collected data, whether digital or traditional, are subsequently compared, stored, and used for various purposes, ensuring a comprehensive approach to wildlife monitoring and conservation efforts. As these field operations require careful collaboration and specialized equipment to be carried through the environment, each step of the DVC is characterized by challenges related to coordination, technological and technical requirements, and other operational factors. For example, the first step of the DVC comprises data collection from IoT devices, which guides the teams' activities in the field because they must gather additional data that will be less structured but characterized by highly informative content. Then, these two data sources must be standardized and stored. The collection, use, and curation require special attention with specific team members ensuring proper management. Further examples of this multi-faceted aspect of data management regard the collection of other types of data, such as GPS tracks, physical and biological samples, and direct and digital observations. These various formats require additional attention in order to prevent losses and duplication.

These examples demonstrate how challenges arise along multiple steps of DVC. In this context, the DVC describes the management of diverse data types from various sources, generated through complex human activities, human-machine interactions, advanced technologies, and external collaborations. Given the coexistence of traditional and digital technologies required to collect and share information, combined with the variety of complex activities involved for environmental safeguarding, managing the DVC becomes particularly challenging. These features motivated us to explore it in depth.

Case study design and data collection

To examine the DVC configuration in GC contexts, we selected the case study methodology, as it is particularly suitable for enabling in-depth exploration of real-world phenomena characterized by complex scenarios (Eisenhardt, 1989; Eisenhardt et al.,

2016; Strauss & Corbin, 1999). A case study is a qualitative research strategy designed to investigate contemporary phenomena within their real-life context that allows for in-depth explorations of complex organizational settings (Eisenhardt, 1989) This methodological approach allows for a rich and systematic examination of heterogeneous data sources, multi-actor collaboration, and intertwined physical-digital processes, typical conditions of GC settings (Eisenhardt et al., 2016). Therefore, it represents a strong fit with our objective of understanding how the DVC unfolds in practice and how challenges emerge across stages.

In this study, the case study methodology enables us to capture the intricacies of data governance, heterogeneous data sources, and multi-actor collaboration in a GC setting. Data management in the context of grand challenges involves heterogeneous data sources, multi-actor collaboration, and intertwined physical and digital processes, conditions that require an in-depth investigation. This method enabled us to understand how the DVC unfolds in practice and how challenges emerge and are managed across the DVC stages. This approach is consistent with prior research on data governance and technology-in-use in complex settings, where rich qualitative data are necessary to understand processes, interactions, and configurations. Therefore, we developed a single case study to investigate how data management occurs in an organizational context characterized by highly heterogeneous data, simultaneous use of digital and traditional tools to handle them, and multiple collaborations with several stakeholders. By unpacking data management activities, we explore the DVC and identify the challenges at every step. To conduct this case study, we rely on three primary sources of data, including archival documents, interviews, and participatory observations (Yin, 2003).

Firstly, we collected secondary data concerning the organization's initiatives, involved actors, activities, technologies, and projects. This phase included the collection of various types of secondary data, such as strategy reports, articles, newspapers, posts, scientific studies, and datasets to gather valuable information from multiple sources (see Appendix 1). The primary purpose of starting the collection with secondary data was to prepare for the subsequent phase of interviews, enabling a more informed and targeted approach (Eisenhardt, 1989; Eisenhardt et al., 2016; Yin, 2003).

Secondly, we conducted 16 open-ended interviews with PNALM members who held diverse roles and backgrounds, including the director, managers, rangers, auxiliaries, and external actors. In total, these interviews spanned 11 hours and 14 minutes (see Table 12 and more detailed information in Appendix b). The interviews were guided by a protocol that included questions about roles, monitoring activities, technologies, relationships, data sharing, and collaborations. The protocol served as a flexible thematic guide, and respondents were encouraged to elaborate freely on their experiences. All interviews were recorded, transcribed, and coded to identify relevant topics and develop the case study.

TABLE 12 Summary of the interviews II

Interview	Actors	Duration
PNALM Site	Director, managers, rangers	5 interviews, 4h 43m
PNALM Site	Chief ranger, rangers, auxiliaries	4 interviews, 3h 20m
Remote call	Rangers, biologist	4 interviews, 1h 35m
Remote call	Tech. providers, ranger	3 interviews, 1h 36m
		16 interviews, 11h 14m

Finally, the Director of the PNALM granted us permission to participate in the activities as volunteers for a period of 8 days. During this time, we gathered detailed data through participatory observations, focusing on the activities and technologies used. These data were recorded in the form of fieldnotes and expanded through an out-of-the-field dictionary (Van Maanen, 1988; Walford, 2009). This approach allowed us to capture a comprehensive understanding of the organizational dynamics and data management practices. Therefore, by triangulating data across multiple sources, we increased the reliability of our findings.

Data coding

To analyze the data, we adopted an open coding approach grounded in qualitative research (Krippendorff, 1980, 2018; Williams & Moser, 2019). Open coding enabled us to identify concepts directly from the data, iteratively develop categories, and progressively link

them to the emerging dimensions of the DVC. This approach is widely used in qualitative research to uncover underlying patterns and to construct theoretically meaningful insights from rich empirical material. Our coding process involved breaking down qualitative material into parts, called codes, to uncover conceptual categories (Strauss & Corbin, 1999). This analytical step enables researchers to remain grounded in the data while progressively abstracting higher-level themes. This approach was followed by the refinement and regrouping of codes to identify various organizational features for data governance. A coder was involved in the process and worked through continuous iterations with the other researcher to incorporate multiple perspectives and enhance the reliability of the coding (Krippendorff, 1980).

The coding process was applied across multiple data sources, including archives, interviews, and observations. This process was firmly grounded in the conceptual framework of the DVC. In the first step, we developed a vocabulary where each part of our data was categorized into specific dimensions of the DVC. This phase was crucial in structuring our understanding of how data-related activities were distributed across the DVC. We then identified and grouped the activities according to each step of the DVC, from data acquisition to data usage. Table 13 outlines the definitions of each DVC step, as derived from the literature, and pairs them with examples directly sourced from our data. Additionally, it introduces three key dimensions, physical, organizational, and digital, that we have developed based on the literature. This table illustrates the connection between theoretical constructs and practical applications observed in the field, highlighting their manifestation in real-world operations within PNALM.

TABLE 13 Definition and samples of DVC and Dimensions

Topics	Meaning	Samples from data
1. DVC Phases		
Data acquisition	All the processes by which data are collected, checked, and organized.	*"I take care of all monitoring, management, and sometimes research of wildlife entities." (extract from interview I)*
Data analysis	All the processes making data ready for domain-specific usage, such as exploring and highlighting relevant information	*"Knowing how many animals are born in a year and knowing the year before how many were born, we know what the survival key is in the first year." (extract from interview XIII)*
Data curation	The active management of data over their lifecycle to ensure their quality and reliability for effective usage.	*"Spatial and temporal data are cross-referenced, and errors may often be made, but the aim is to minimize them, for storage and subsequent analysis." (extract from interview I)*
Data storage	The persistence of data needed to be available for access and reuse in a scalable way.	*"Cards are collected, and, at the end of the sampling, we collect all the data, file it in the database, and start to think." (extract from interview V)*
Data usage	All data-driven business activities require data as a tool to obtain advantages in performance.	*"Data used for management, territorial surveillance, to try to correct animal behaviors in some way, or to answer several research hypotheses." (extract from interview XIII)*
2. Dimensions		
Digital	The technical dimension of activities or operations supported by digital technologies and tools such as IoTs, sensors, and platforms.	*"We make a digital card that our system collects, and then, the technical office, based on the data we give them, processes the information." (extract from interview V)*
Organizational	The organizational processes and arrangements that enable members to conduct coordinated and seamless operations.	*"On a specific wildlife, we perform simultaneous counts to gather useful insights (extract from interview XIII)*
Physical	The spatial or tangible dimension of activities and operations conducted off-site, beyond organizational boundaries	*"We usually go together to the mountain, also with researchers from universities to share our knowledge." (extract from interview X-XI-XII)*

During this phase, we aligned our data according to the DVC framework. Then, we categorized and quantified the occurrences of both digital and traditional technologies used in each DVC step. Subsequently, using NVivo software, we analyzed the frequency and co-occurrences of digital and traditional technologies at each step of the DVC (see Appendix 3).

The next phase involved documental and content analysis, through which we identified the challenges associated with the steps of the DVC. We further examined the nature of these challenges, determining whether they were technology-related or not, considering the complex nature of the DVC under study.

Content analysis

Once the first phase was completed, we had our data framed according to the DVC steps, from data acquisition to data usage (Appendix 3). With this framework in place, we proceed with the actual coding process to identify and categorize the challenges. We coded both secondary and primary data sources (Gioia et al., 2013; Strauss & Corbin, 1999).

Documental analysis. We developed conceptual categories based on the characteristics of each document (see Appendix 1). Documents were read and analyzed to identify relevant segments of text related to data management and technologies. These segments were then incorporated into the content analysis.

Content analysis. According to (Creswell, 2014) content analysis should involve transcribing the thematic content of the data and highlighting relevant themes within the text. In the coding phase, we thoroughly analyzed our data, selected parts of the text, and assigned them to nodes. We then aggregated the selected nodes into themes based on their contents and further aggregated them into dimension sources. We then aggregated the selected nodes into themes based on their contents and further aggregated them into dimensions (Gioia et al., 2013; Magnani & Gioia, 2023). We systematically read each part of the texts, highlighted the most relevant themes, and coded them by assigning them to nodes. We developed a visual representation of the analysis, showing raw data, first-order concepts, and themes. The initial part of this procedure consisted of identifying relevant raw data from the interviews and categorizing them into first-order concepts. These concepts are labels describing relevant activities, tools, structures, and artifacts. Through content analysis, we identified an array of challenges and three dimensions. Finally, in the subsequent step, we explored the relationship between the emerging concepts.

Tables 14 and 15 show the results of our coding.

TABLE 14 Data Coding Structure – Challenges

Data Value Chain	Coding of Challenges	Coding of Concepts
Data acquisition	Collecting dislocated data	• Gathering from multiple data sources and formats • Enhancing operations through digital technologies • Multiple digital data sources • Managing enabling technologies lacks
	Enriching data through human intervention	• Gathering unstructured data • Concurrent on-site data collection • Collaborative qualitative evaluations
Data analysis	Analyzing spatial and temporal data	• Combining spatial and temporal data • Finding insights from displaced devices • Cross-analysis of data
	Processing heterogeneous data	• Preliminary qualitative evaluation • Analysis of physical samples • Finding insights from limited valuable data
Data curation	Centralized data validation	• Centralized data flow • Avoiding duplication through cross-check
	Observational data harmonization	• Transforming physical samples • Managing flexible data sources • Cross-checking observational data
Data storage	Additional data warehousing	• Direct data warehousing • Overcoming database limitations
	Remote digital sampling	• Digitizing paper reports • Mapping track to GPS data
Data usage	Joint decision-making support	• Discovering new trends and patterns • Development of models • Managing two-way information flow
	Operation improvements	• Meetings for strategy development • Linking discoveries to on-site operations

TABLE 15 Data Coding Structure – Actors and Dimensions

Configuration	Actors and Dimensions	Coding of Concepts
Dimensions	Digital dimension	• Technologies for data collection • Technologies for data analysis • Technologies for information sharing • Technological implementation in projects
	Organizational dimension	• Activity planning and role definition • Information sharing • Collaboration • Meetings
	Physical Dimension	• Field activities across the territory • Displaced data collection • Physical samples gathering
Actors	Internal (PNALM)	• Scientific units responsible for data management • Internal collaborators conducting data analyses • Dedicated multiple units to gathering data
	Public Organizations	• Data sharing with public environmental institutions • Research collaborations with universities • International partnerships with public entities • Biological analysis with public laboratories
	Private Organizations	• Agreements with technology providers • Scientific studies with external researchers • Partnerships with private organizations

The following tables 16 and 17 illustrate the data coding and representative quotes alongside the results of our coding process.

TABLE 16 Data coding and representative quotes of Challenges

Second-order themes and first-order concepts	**Representative quotes**
Second-order theme • First-order concept	*'Representative quote'*
Collecting dislocated data	
• Gathering from multiple data sources and formats	*We make observations through binoculars, scopes, photo traps, genetics, radio collars, and public data (extract from interview I)*
• Enhancing operations through digital technologies	*We can increase the observation window through specific tools during direct observations (extract from interview XIII)*
• Multiple digital data sources	*We rely on photo traps, radio collars, mobile app… (extract from interview V)*
• Managing enabling technologies lacks	*If there is a lack of connection, there is a lack of communication between teams collecting data and me analyzing them (extract from interview X)*
Enriching data through human intervention	
• Gathering unstructured data	*[during observations] There are evaluations that extend beyond simple counting (extract from interview I)*
• Concurrent on-site data collection	*On a specific wildlife, we perform simultaneous counts to gather useful insights (extract from interview XIII)*
• Collaborative qualitative evaluations	*We simultaneously track samples by recognizing permanent or artificial markings (extract from interview I)*
Analyzing spatial and temporal data	
• Combining spatial and temporal data	*Spatial and temporal data are cross-referenced (extract from interview I)*
• Finding insights from displaced devices	*We combine photo trap data with data from observations (extract from interview I)*
• Cross-analysis of data	*We have a database and a spatial reference system that we intersect to produce e.g., maps (extract from interview XIII)*
Processing heterogeneous data	
• Preliminary qualitative evaluation	*It is crucial to conduct an initial analysis of the data, comparing them, to avoid counting it twice (extract from interview I)*
• Analysis of physical samples	
• Finding insights from limited valuable data	*The data are not particularly robust, but they allow us to understand what the population trend is (extract from interview X)*
Centralized data validation	
• Centralized data flow	*The scientific service is the office that deals with gathered data (extract from interview VII) - It is very important to compare data to avoid duplication (extract from interview I)*
• Avoiding duplication through cross-check	
Observational data harmonization	
• Transforming physical samples	*We collect genetic samples and the genetic data, which allow us to discover insights*
• Managing flexible data sources	*We use traditional tools when the databases don't align with our needs.*
• Cross-checking observational data	*Collect data and then compare them; this then also allows you to have a more objective view (extract from Interview XVI)*
Additional data warehousing	
• Direct data warehousing	*We directly gather data into the server (extract from Interview V)*
• Overcoming database limitations	*We then must modify the databases according to our needs (extract from Interview I)*
Remote digital sampling	
• Digitizing paper reports	*We fill in the paper reports. They go to the scientists, and they integrate with them to get all the data stored (extract from Interview V)*
• Mapping track to GPS data	*We trace the route with a GPS system and then e-mail it to the scientific service (extract from Interview VII)*
Joint decision-making support	
• Discovering new trends and patterns	*Photo traps, as well as samples, are also minimally invasive systems to discover all behavior. - These data can also be transformed into models for predictions.*
• Development of models	
• Managing two-way information flow	*With the GPS, we download data, the data would go directly to the scientist and then be turned over to the park rangers (extract from Interview VII-XIII)*
Operation improvements	
• Meetings for strategy development	*With the new insights… usually, we organize meetings to share them or make decisions*
• Linking discoveries to on-site operations	*On the basis of data, we process information and then the subsequent interventions (extract from Interview XIII)*

TABLE 17 Data Coding and representative quotes of Actors and Dimensions

Second-order themes and first-order concepts	**Representative quotes**
Second-order theme • First-order concept	*'Representative quote'*
Digital • Data management technologies • Communication technologies • Technological integration in projects	*'Technology is now being applied in various fields, for example, in projects or wildlife monitoring, even on critical species such as the Marsican brown bear population. - Without technology for genetic analysis, a range of information would be missing. (extracts from Interview IV)*
Organizational • Activity planning and role definition • Information sharing and coordination • Stakeholder collaboration • Meetings and discussions	*'The technical, wildlife, and scientific services receive reports 24/7. These reports are sorted by type and forwarded to the relevant sector. The headguard is notified and, depending on the situation, contacts the appropriate guards, who then prepare and go out.' (extract from Interview V)* *We usually organize meetings to share insights or make decisions (extract from Interview XIII)*
Physical • Field activities across the territory • Displaced data collection • Physical samples gathering	*'We tracked wolf footprints in the snow, mapping the path using a GPS system. The data is then collected and forwarded to the scientific service for analysis. (extract from Interview IX)* *We collect biological samples for DNA analysis, allowing us to count, identify animals, and determine parameters like sex ratios. (extract from Interview XIII)*
Internal (PNALM) • Scientific units responsible for data management • Internal collaborators conducting data analyses • Dedicated multiple units to gathering data	*Collected data are shared with the scientific unit, which will conduct the first analysis (extract from Interview VIII)* *Some analyses are easy to handle with our own tools and skills. When more specialized expertise is required, we naturally seek external support. (extract from Interview I)* *'We do simultaneous counts with rangers and scientists.' (extract from Interview I).*
Public Organizations • Data sharing with public environmental institutions • Research collaborations with universities • International partnerships with public entities • Biological analysis with public laboratories	*'We collaborate with the regions for a series of needs on activities such as hunting or on infrastructures' (extract from Interview I)* *'We do activities with universities because they do a whole series of monitoring aimed at developing management guidance' (extract from Interview I)* *We monitor signs of presence, collect samples, and then send them to 'Public Agency (anonymized), which conducts the genetic analysis, so we can identify the species with animal-specific recognition.' (extract from Interview IV)*
Private Organizations • Agreements with technology providers • Scientific studies with external researchers • Partnerships with private organizations	*'Often we are able to take genetic samples, and then the genetic data are sent to genetics laboratories.' (extract from Interview I)* *'We analyzed tourist flows through cell towers, and we entrusted this work to the 'Private Company' (anonymized).' (extract from Interview IV)*

Content analysis was employed to analyze and explore the themes that emerged from the analysis. We further analyzed the codified data with NVivo software using the Matrix Coding Query feature. This feature allowed us to find coding intersections between lists of items. This feature enabled us to analyze the coded data with co-occurrence analysis and find patterns among nodes. We determined co-occurrences by counting the number of words within sentences that referred to the concepts under study. This analysis unveiled the type of challenges at each step of the DVC and linked them with their related

dimensions. By dimensions. Table 18 shows the results of our Matrix Coding Query, highlighting the links between the challenge dimensions and the DVC phases. It quantifies the frequencies of words related to dimensions of challenges and their corresponding phases in the DVC.

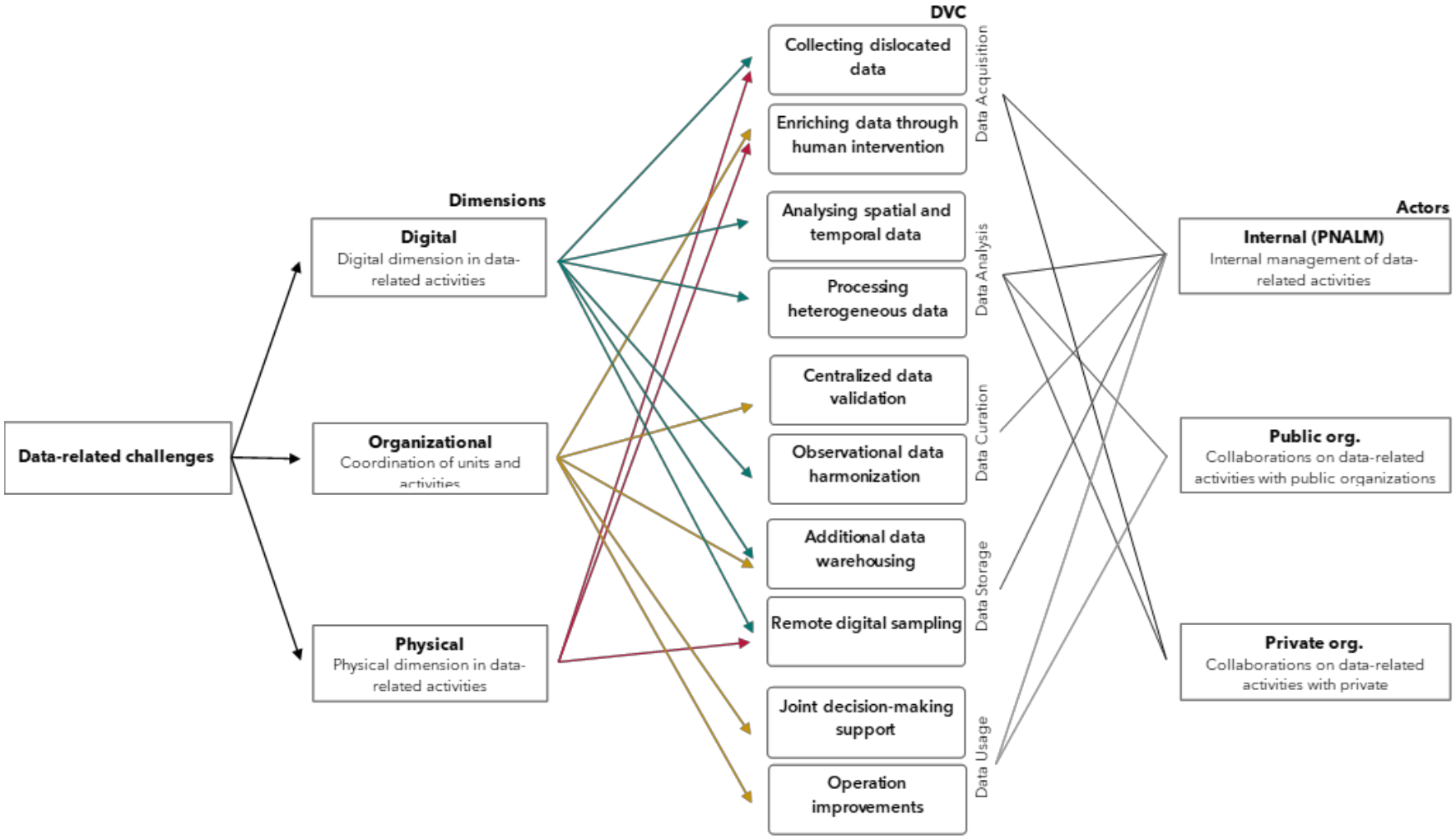
TABLE 18 Matrix Coding Query: DVC Challenges and Dimensions

	Dimensions		
DVC Phases	**Digital**	**Organizational**	**Physical**
Data Acquisition	**379**	**322**	**458**
Data Analysis	**714**	80	120
Data Curation	**353**	**303**	15
Data Storage	**301**	**305**	**232**
Data Usage	181	**842**	165

Findings

We analyzed data management operations involved in organizing and coordinating the DVC by PNALM. Engaged in environmental safeguarding initiatives, the organization manages vast amounts of data from multiple sources, including both unstructured and structured data. These data are used to support tackling societal challenges through research, knowledge, and operational improvement, and informed decision-making. Our findings highlight a range of challenges across three categories: technical, organizational, and managerial dimensions. These dimensions represent a taxonomy of challenges that organizations face in data management operations along the DVC. They underscore the importance of managing technological aspects alongside human activities to ensure effective solutions, particularly in contexts where multiple actors, teams, or units handle heterogeneous and dispersed data both on-site and off-site. Figure 7 illustrates the configuration of the data value chain within grand challenge contexts.

FIGURE 7 Array of the Data Value Chain Configuration in Grand Challenge Contexts



Physical dimension

In our analysis, we found that the physical dimension represents a crucial aspect within the DVC, particularly in the phases of data acquisition and data storage. Indeed, these phases exhibit greater complexity due to the need to collect and store dispersed data across vast territories, relying on both technology and human efforts. In our context, we identified two complementary approaches to data collection. This process is driven by IoT technologies providing data about key areas for wildlife. Further, the data collected from these technologies is then enriched, where necessary, with observational qualitative data, offering a broader perspective on the phenomena being studied. As a result, the challenges related to the physical dimensions of data collection are two-fold. Therefore, the first approach relies on technologies including sensors and IoT devices, which are designed to gather distributed rich data from throughout the territory. The second approach, closely linked to the first, entails the collection of qualitative unstructured data directly from organizational members engaged in data collection activities, enriching the data with depth and details. Traditional tools for data collection included, for example, paper sheets on which teams reported additional evaluations, telescopes and visors to increase the observation window, and the collection of samples from the fields. As one interview explained:

"We have been using GPS radio collars for many years to track and study their movements and behaviors, and photo-traps to increase the chance of seeing the females with their cubs… Observations are made through the use of binoculars and, of course, spotting scopes, as they allow you to somehow get more details on behaviors." (extract from Interview XIII)

"We collect genetic samples and then process genetic data… We trace the route with a GPS and then send it to the scientific service." (extract from Interview IV)

To address this dual nature of data originating both from digital technologies and human activities, organizations face several data storage challenges related, for example, to data veracity, integrity, and flexibility of their warehousing process. These challenges of a physical nature become more complex when the collected data include physical samples, especially if gathered off-site, as they require effective storage solutions to prevent loss. Members must physically search for, identify, and collect samples, track their route or

position, and store them in either physical or digital form, all while preventing information loss. To overcome these challenges, particular attention must be given to the sharing process among various organizational areas or units, the digital infrastructure needed to store them, and the flexibility of warehousing processes in terms of technologies and tasks. According to one interview response:

"We collected the data during this last season and then we will pass it on to the scientific service so it will be additional checks." (extract from Interview IX)

"I put data directly into the server. It is stored there, and the scientific service opens and sees." (extract from Interview VI)

As data exhibit heterogeneity in numerous aspects, such as format and type, the challenge is to manage and store them to avoid information loss, which may negatively impact the results.

"We set specific days for simultaneous observation: rangers and the scientific service ascend to high altitudes with binoculars and spotting scopes to record and mark all the units… There are evaluations that extend beyond simple counting, through permanent or artificial markings, we determine whether to collect that novel data or whether it has already been collected." (extract from Interview I)

Addressing this heterogeneity is crucial to avoid standardization problems in the subsequent steps of the DVC (Wirén et al., 2019). Overcoming these challenges requires both technical and organizational efforts, which we will elaborate on in the following sections.

Digital dimension

Unsurprisingly, our findings highlight the fundamental role of the technical dimensions in data-related activities across nearly all phases of the DVC. Consistent with prior research, technology is central to the DVC, supporting each phase while ensuring the continuity of the operations and the flow of data. This is particularly true in the phases of data acquisition, analysis, curation, and storage, where a variety of tools are employed to support all the activities related to data. Digital technologies such as IoTs and GPS-based systems, software for analysis, and database management systems are essential to both automated and manual operations. These technologies assume paramount importance in

supporting organizations to manage and derive meaningful value from each phase of the DVC. As expressed by an interview respondent:

"Technology is now applied in various fields; we have projects related, for example, to wildlife monitoring, GPS or GSM radio collars allow us to gather and save these data, see what these animals are doing in real time, and study them." (extract from Interview VI)

Analyzing dispersed and heterogeneous data presents a significant challenge in our context for several reasons. First, structured and unstructured data are combined before the analysis in order to extract rich insights.

"We cross-reference spatial and temporal data, and, as errors can be made, our aim is to minimize them for storage and subsequent analysis. The aim is therefore to use more advanced software." (extract from Interview I)

Once data are gathered across the territory, managing their heterogeneity becomes essential. Integrating unstructured data into analysis represents a major challenge that organizations face at this stage. For example, to conduct a study of the wildlife population in a specific area, PNALM must integrate geolocation data, observational records, and physical samples. As the complexity of the analysis grows, so does the heterogeneity of the data to be included.

"We combine photo trap data with data from observations." (extract from Interview I)

While technologies provide rich quantitative data, qualitative observations require greater human efforts due to the challenges of collecting limited yet valuable information within the wild landscape. A big challenge lies in further developing the database through close collaboration between the developers and those who work in the field, in order to meet their specific needs. This collaboration ensures that the database evolves to align with real-world requirements and maximizes its utility. This is particularly important for integrating insightful data from human activities, which are inherently unstructured and qualitative, making it more complex to incorporate into the database. As highlighted by one interviewee:

"Often, we prefer to request paper records, and then we modify the databases as needed. It provides an opportunity to identify errors, duplicate entries, or other discrepancies directly on the document." (extract from Interview I)

"The platform is helpful, but significant challenges remain. Creating a unified system requires effective communication between app developers and analysts. Without this collaboration, we risk encountering numerous issues related to data sources and types" (extract from Interview X-XI-XII)

Organizational dimension

Our findings underscore the fundamental role of the organizational dimension in addressing the challenges throughout the DVC. These challenges are particularly evident in complex settings, where organizations face significant coordination challenges related to gathering meaningful, dispersed data and managing them effectively. Such challenges emerge most notably in contexts involving field activities, such as manufacturing sites or logistics operations, as well as in contexts characterized by organizations tackling large or local-scale societal issues like combating poverty or safeguarding the environment (Angeli et al., 2022; George et al., 2016). This is due to the prominence of activities conducted directly in the field, where data must be collected off-site. This peculiarity must be managed through effective coordination mechanisms. Indeed, the main challenge we identified in our empirical context relates to the coordination of teams engaged in data-related activities across the vast territory. These teams must organize monitoring plans, ensuring that they are allocated to specific zones within designated time frames, while sharing real-time updates to make sure to prevent data issues such as duplication or loss. As expressed by one interviewee:

"We perform evaluations that extend beyond simple counting. On specific wildlife, we perform simultaneous counts to gather useful insights and track specific animals such as breeding units." (extract from interview I)

The need to enrich data through human interventions creates an additional layer that organizations must address for effective data management. During the data acquisition phase, we found that coordination challenges arise from human activities aimed at enhancing the automated data collection provided by digital technologies. By organizing

observation operations, field research, and other data-related activities, organizations must manage team dynamics and coordination mechanisms to ensure comprehensive data collection. Therefore, data collected off-site must be checked and evaluated before being stored in the database.

"At the end of the sampling, then, we collect all the data, store it in the database, and start reasoning." (extract from the interview I)

According to our findings, data sharing with assigned organizational units may support centralized data check and evaluations, facilitate the management of heterogeneous data flow, thereby ensuring data integrity and veracity before the storage process. In our case, the scientific area is designated to receive and manage the data flow, supporting the subsequent steps necessary to extract value from data during the data usage phase. Finally, within the data usage phase, we found mechanisms for improvement and involvement of diverse members to make joint strategic and operational decisions. Meetings were used as a coordination tool for decision-making and operational improvements.

Finally, we identified adaptive management as the primary goal of data-related activities, aimed at ultimately improving organizational outcomes. By analyzing data, organizations can identify emerging trends and patterns, develop predictive models, and facilitate information sharing across different organizational units to enhance future operations and overall knowledge base. Below, we present excerpts from interviews that support these insights.

"We can conduct a study of the characteristics of a bear's wintering areas. This data can then be transformed into models that predict, for example, which areas are the most critical." (extract from Interview XIII)

We observed the use of data for various purposes, including research studies and ongoing monitoring activities, which build upon insights gained from previous data. In addition, meetings for strategy development and operations improvements typically occur to progressively reduce uncertainty and inform decision-making with new insights.

"Meetings have several functions: not only to inform, but also to make all participants feel that they understand what the difficulties are..." (extract from the interview I)

"There are also some presentations to involve and describe activities. So, there is a moment, maybe more of office 'lectures', let's call them that, through presentations." (extract from the interview XIII)

"We use adaptive management, so we monitor and if we see that the actions don't bring results, we try to understand and then we readjust what didn't work. We do activities with the universities; they do a series of monitoring also aimed at developing management guidance." (extract from interview I)

In conclusion, the organizational dimension plays a bridging role between the technical and the physical settings, ensuring coordination among units and members. Overcoming organizational challenges along the DVC means ensuring proper data management throughout the entire process, supporting operations, facilitating seamless information sharing, allocating tasks efficiently, and engaging members in decision-making and improvement processes.

"We set up a monitoring system to create a group of experienced personnel who know how to recognize the signs of presence, collect biological material." (extract from Interview I)

Actors

The analysis highlights the pivotal role of multiple actors in configuring the DVC, each with distinct functions across its various steps. While the organization manages every stage of its DVC, we identified collaborations with both public and private entities as essential for providing tools, expertise, technologies, and overall support. Our findings demonstrate how these collaborations serve as capacity builders, enabling the organization to manage the increasing complexity associated with data. Specifically, to address challenges such as data heterogeneity, complex analyses, and the use of advanced analytical tools, the organization actively seeks and fosters collaborations that push technological boundaries and enable the development of transformative projects.

The following is an example of a data path that begins with internal management, proceeds through outsourced analysis conducted by a public partner, and returns to internal use of the extracted information for value generation:

"*Technology is now applied in various areas. We have a project related, for example, to wildlife monitoring, like tracking the population of the Marsican brown bear. In that case, this technology involves equipping the animals with radio collars and then following their movements over time. You download the data, and you see what the animals are doing across the territory. That's an important technology" (extract from Interview IV).*

Then the interviewee went on to explain:

"*We also monitor signs of presence, collect samples, and send them to "Public Agency" (anonymized), which conducts the genetic analysis. It's kind of like fingerprinting the animals. These analyses, of course, provide significant information over time, from population indications to information on how these animals move… This is a project where technology might seem marginal, but it actually makes a real difference. Without genetic analysis or satellite radio collars, you would obviously miss out on an entire range of information." (extract from Interview IV).*

On the other hand, the following is an excerpt from an interviewee representing a private company partnering with PNALM:

"*We provide the technology. Then, they are the ones who carry out the data analysis, assess the situation, and run their cross-analyses and statistics… We collect the data and then pass it on. So, we don't really deal with the analysis; that's not part of our role." (extract from the Interview XIV-XV).*

These findings highlight the crucial role of public–private partnerships in enabling PNALM to address the growing complexity of data by seeking expertise and technologies beyond its organizational boundaries, while maintaining full control of its resources.

In our analysis, while internal management takes care of each step of the DVC, the interaction with public organizations occurs mostly for data analysis and data usage for policy development. In our analysis, while internal management oversees each step of the DVC, interactions with public organizations occur primarily during the data analysis phase and in the use of data for policy development. Conversely, collaborations with private organizations are concentrated on the data acquisition and data analysis steps, as

private companies in our study acted as technology providers or supported specific, complex analyses.

Discussion and Conclusion

Organizations are increasingly leveraging data to enhance their understanding of their context and surrounding environment. To extract greater value, data must be collected, shared, and managed effectively. The Data Value Chain framework analyses these processes, from data collection to the impact generated by their use within organizations, encompassing actors, roles, relationships, and resources (Curry & Ojo, 2020; M. I. S. Oliveira & Lóscio, 2018).

In GC contexts, organizations involved in DVC activities operate in highly complex environments characterized by multiple actors, diverse objectives, and interconnected data needs, ranging from supporting decision-making to enabling research and adaptive management. The central challenge is to transform heterogeneous data into actionable value while ensuring effective coordination among stakeholders. Our findings illustrate how this process unfolds into the three core dimensions: the physical dimension, which shapes how data are collected and enriched, the digital dimension, which supports each DVC stage through both automated and human-managed systems, and the organizational dimension, which ensures alignment across actors and prevents operational disruptions along the DVC. Within the PNALM setting, we explored a configuration that equally emphasizes the physical setting, achieved through fieldwork for data-related activities, and the digital setting, enabled by automated data collecting and processing (Curry & Ojo, 2020; Davidson et al., 2023) and made important contributions to the DVC literature (Curry, 2016; Wirén et al., 2019).

Contribution to the DVC

Prior studies on the DVC have examined its components and their configuration through several distinct research streams, often treating each dimension as an independent block. These studies typically adopt a single-dimension lens, focusing either on the digital dimension (Åkerman et al., 2018; Curry, 2016; De Simone et al., 2023; Hernández-Moral et al., 2021; Watch, 2017) which focuses on data architectures, digital infrastructure, and

interoperability; or the organizational dimension (Åkerman et al., 2018; Basile et al., 2024; Cavanillas et al., 2016; Davidson et al., 2023; Faroukhi et al., 2020; Urbano et al., 2024) which focuses on governance mechanisms and collaborative teams; or the physical dimension (Åkerman et al., 2018; Cavanillas et al., 2016; Urbano et al., 2024) that emphasize the field-related elements of data. This study offers three main contributions:

(i) we advance a view of the DVC as a multi-dimensional system in which digital, organizational, and physical elements jointly structure data flows, coordination practices, and value generation across heterogeneous actors;

(ii) we disentangle these three dimensions and illuminate the specific constitutive mechanisms through which each dimension influences how data circulates and how value is produced along the DVC;

(iii) by bringing to light the main mechanisms that stem from this multidimensional understanding, we deepen the dialogue between DVC scholarship and GC research and offer new insights into data-driven operations in complex, multi-actor environments.

As our first contribution, we conceptualize the DVC as an integrated multi-dimensional system, combining digital, organizational, and physical dimensions, and demonstrate how their interdependencies co-construct data flows, coordination mechanisms, and value creation in complex, multi-actor settings. This perspective extends existing literature by moving beyond linear views of the DVC, offering a practically relevant framework for understanding and managing data-driven value creation (Curry, 2016; Curry & Ojo, 2020; Davidson et al., 2023). Our study shows that managing the DVC as an integrated multi-dimensional system enables organizations to extract value from heterogeneous data by fostering collaboration, technological integration, and actionable insights in complex, multi-actor settings. The digital, organizational, and physical dimensions are inherently interconnected and often co-occur in multiple configurations along the DVC. These interdependent dimensions jointly shape how data is collected, processed, and exploited in GC contexts. Rather than functioning as separate layers, they interact and co-evolve, influencing how data flows, is enriched, and is ultimately leveraged across intricate organizational environments. Spatial characteristics, technological configurations, and coordination mechanisms are not independent but co-construct the ways data is collected, enriched, and circulated. In complex settings characterized by off-site activities and

multiple stakeholders with differing objectives, effective DVC management therefore requires organizations to intentionally structure and integrate these dimensions to ensure coherence and value creation (Curry, 2016; Wirén et al., 2019).

Our second contribution lies in unpacking the digital, organizational, and physical dimensions of the DVC and clarifying the constitutive mechanisms through which they shape data flows and value creation. We show that the digital dimension not only enables data collection and processing across the DVC but is also shaped by technological properties, the actors who interact or operate with them, and their spatial distribution, highlighting its central role in configuring multi-actor, socio-technical data flows as well as providing the foundation for data governance decisions. The digital dimension spans the entire DVC, encompassing digital infrastructures, automation, and data processing, while continuously interacting with and being complemented by human involvement (Curry & Ojo, 2020; Davidson et al., 2023). Our findings indicate that this dimension plays a central role in the DVC, with digital technologies often initiating and enabling the early stages of the value chain. By driving data collection, processing, and preliminary analysis, the digital dimension sets the foundation for subsequent data-related activities, highlighting its pivotal role in shaping data flows across complex, multi-actor environments (Davidson et al., 2023; De Simone et al., 2023). In such contexts, data governance concerns enabling the data flow and is shaped by the properties and distribution of the technologies employed, the actors who own and interact with them, and their technological infrastructures that can influence functionality, accessibility, and interoperability. The combination of automated processes and human interventions underscores the socio-technical nature of the DVC. Together, these interdependencies emphasize that effective configuration of the digital dimension requires attention not only to the technologies themselves but also to the actors and spatial arrangements, reinforcing its link with the organizational dimension and overall DVC management (Curry & Ojo, 2020; Wirén et al., 2019).

To advance this second contribution, we further demonstrate that the organizational dimension plays the role of the integrative mechanism of the DVC. By coordinating actors, roles, and processes, this dimension aims to align human, technological, and physical components, thereby ensuring coherent data-driven operations across complex, multi-actor environments. The organizational dimension enables the coordination of

actors and roles within DVC activities, relying on mechanisms such as structured and non-structured meetings, role allocation, task assignments, real-time information sharing, and digital communication. These arrangements complement and enrich the data generated through digital technologies, support validation and storage processes, and, above all, support data-driven decision-making and operations. By linking the technical systems with physical data practices, the organizational dimension acts as a bridge that aligns human, technological, and physical components of the DVC. In doing so, it ensures coherence and continuity across the DVC, ultimately enabling it to function as a seamless human-technical system (Curry & Ojo, 2020; Davidson et al., 2023).

To conclude this contribution, we show that the physical dimension, encompassing spatial features and location of operational settings, plays a crucial role in shaping data collection, integration, and flow within the DVC, highlighting how managing spatial configurations and physical data samples influences coordination, data management, and multi-actor operations (Åkerman et al., 2018; Cavanillas et al., 2016; Urbano et al., 2024). This dimension encompasses the spatial characteristics of the operational settings, including size, scale, location, and the type of interactions and data sharing, whether the data are digital or traditional (Åkerman et al., 2018; Cavanillas et al., 2016; Urbano et al., 2024). Data collected off-site, for example, may come from large or localized fields and must then be integrated with digital systems and managed effectively across divisions. Data are shared among members and transferred to designated units or teams, where both digital and physical samples must be managed effectively. These considerations assume crucial importance for organizations that must address this complexity while managing DVC operations. Addressing the physical dimension leads to the necessity of supporting a seamless flow of data throughout the DVC steps, ensuring coordination among human activities and technologies. Managing the physical dimension thus requires ensuring a seamless flow of data throughout the DVC, coordinating human activities and technological processes (Cavanillas et al., 2016).

Finally, in our third contribution, by highlighting the major mechanisms that arise from this multidimensional view of the DVC, we strengthen the link between DVC research and GC studies (Akter et al., 2024; Angeli et al., 2022; Ferraro et al., 2015; Gümüsay et al., 2022b). In doing so, we show how data and information systems can support societal goals, such as environmental sustainability, social development, and well-being, by

informing data-driven actions and enabling coordinated use of heterogeneous data across multiple actors. The three dimensions we identify offer a benchmark for organizations managing off-site activities, where data must be integrated at both physical and digital levels. Recognizing these challenges enables organizations to anticipate criticalities, configure technology effectively, and coordinate activities efficiently, thereby maximizing the value of data-related operations while reducing inefficiencies and information loss. As grand challenges are inherently collective, public-private collaborations act as catalysts for technological innovation, transformative projects, and analytics deployment. Such collaborations foster long-term partnerships, creating data ecosystems that enable cross-sector synergies, joint value creation, and sustained innovation. By connecting diverse actors, including data providers, technology developers, research labs, and public agencies, these data-based networks support value creation and innovation that transcend individual projects (Adner & Kapoor, 2010, 2016; Cavanillas et al., 2016; Cennamo & Santalo, 2018; Jacobides et al., 2018).

Implication for practitioners

Our contribution offers actionable guidance for managers, professionals, and other practitioners involved in the configuration and management of the DVC. A clearer understanding of the emerging dimensions can enhance data governance practices and support more effective planning, identification, and configuration of data-related processes, ultimately enabling organizations to extract meaningful value from their data. Accordingly, this research provides several practical implications for practitioners by highlighting how a multidimensional view of the DVC can inform decision-making, improve coordination across actors and technologies, and foster more coherent data-driven operations. While enabling technologies are essential, particularly when data is collected directly from the field, it remains essential to acknowledge that some challenges cannot be addressed solely through technological solutions. It is not surprising that the digital dimension is present in all the stages of the DVC. However, effective organizational arrangements are equally essential for effective data governance. The organizational dimensions should be a priority as organizations must overcome several coordination challenges along the DVC. This dimension is a bridge between technological and human activities related to data. For example, organizations should

facilitate inter-unit collaboration and coordination to maintain a constant alignment of tasks, operations, and processes throughout the DVC.

Data governance should prioritize real-time coordination mechanisms, such as in-person meetings or shared digital platforms, to align teams and balance digital and human input. This approach promotes inter-unit information sharing and collaboration. Effective DVC management is not solely about adopting the right tools; it also requires orchestrating physical logistics, including off-site data collection, technical systems such as platforms and devices, and organizational coordination, ensuring people and processes are not overlooked. While orchestrating these internal dimensions, it is equally crucial to foster public-private collaborations, which can open new opportunities. DVC management should be carried out in partnership with public and private organizations that can contribute to import expertise, tools, and knowledge. These collaborations are key to configuring a robust data ecosystem that enables value creation from data and unlocks the transformative potential of collective innovation projects.

We further examined the value and utility of data within the context of environmental safeguarding. This is a field that requires a multifaceted approach to understanding the environment and progressively improving the impact of organizations in addressing the challenge. Effective data-related activities foster organizations optimize the exploitation of data value and improve the understanding of the peculiarity of the context. Two phases of the DVC strictly relate to the physical dimension: data collection and data storage. Since these dimensions refer to the collection of dispersed data off-site and their storage, organizations should strengthen this link in two ways. First, by strengthening the link between the two phases through automated data gathering and warehousing via IoTs or digital technologies, organizations may reduce the human workload. Incorporating additional data sources of different types would further improve both the data collection phase and subsequent storage. Second, coordination mechanisms can strengthen the 'human dimension' along the DVC by improving inter-unit collaboration, information and knowledge sharing, and task division. This is especially important for conducting simultaneous off-site activities.

Organizations embracing an adaptive management approach can take advantage of the new insights gained through the DVC steps by extracting value from data and achieving

benefits from them by improving subsequent operations. This scenario makes data a strategic capability, not just an operational task. Data enable feedback loops to develop strategic directions, inform decision-making and operations, ultimately supporting adaptive learning.

Limitations

This study presents some limitations that suggest areas for further research. First, being based on a single case study, the generalizability of the findings may be limited. Replicating this methodology in different contexts could enhance the robustness of the results by identifying additional patterns and improving the overall reliability of the findings (Yin, 2003). Second, while the DVC framework provides conceptual foundations, the challenges identified are closely tied to its steps. Although this approach offers a structured view, it may overly emphasize some challenges at the expense of others, potentially affecting the results and limiting flexibility. Third, this paper aggregates challenges that could be relevant in other domains and thus can constitute the basis for exploring or comparing those challenges across different sectors, such as healthcare, finance, or other GC settings. On a final note, future research could examine how digital technologies, automation, and coordination mechanisms reshape human work along the DVC in GC contexts, where field-based operations and dispersed data sources place distinctive demands on people and routines. Further studies might investigate how organizations adapt workforce composition, roles, and required capabilities across the DVC's interdependent physical, digital, and organizational dimensions, including the skills and training needed to coordinate data practices across boundaries. Understanding these dynamics would help organizations plan workforce strategies, balance human-technology interdependencies, and sustain data-driven action in GC settings and beyond.

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6. Paper III: Collective Action in the Wild: Orchestrating for Grand Challenges in Inter-Organizational Contexts [3]

Paper III adopts an inter-organizational perspective to investigate how a network of organizations orchestrates and mobilizes collective action to address grand challenges. Based on ethnographic observations and interviews, it explores the role of lead orchestrators in facilitating inter-organizational coordination under conditions of limited authority, trust, and resources, and identifies mechanisms that enable collective action. The paper develops a framework showing how orchestration unfolds through three strategies: establishing network leadership, building network legitimacy, and scaffolding network governance. The results highlight the importance of collective leadership, shared belonging, and participatory governance to strengthen network capacity in complex grand challenge initiatives.

This paper is written in collaboration with Prof. Federica Ceci from G. d'Annunzio University and Prof. Andrew Davies from the University of Sussex.

[3] Paper written in collaboration with Federica Ceci – G.d'Annunzio University and Andrew Davies – University of Sussex

Abstract

Orchestrating inter-organizational collaborations is critical for aligning diverse actors, resources, and goals to achieve collective outcomes. In grand challenge settings, this process becomes particularly demanding because lead organizations, i.e., central actors responsible for initiating, coordinating, and sustaining inter-organizational collaboration, often operate with limited authority, power, and resources, exposing networks to coordination failures. Despite growing interest in orchestration practices, the roles of lead organizations in navigating interdependencies, balancing competing interests, and establishing governance remain unclear and require further attention. Drawing on an in-depth case study of the LIFE Bear-Smart Corridors (BSC) initiative, an environmental safeguarding project in Central Italy, we explore how lead organizations orchestrate a network of actors to address coordination failures and advance human-wildlife coexistence. Our model illustrates that orchestrators navigate collective tensions through three key strategies: setting up network leadership, building network legitimacy, and scaffolding network governance to sustain collective action. We argue that orchestration in grand challenges initiatives requires leveraging collective leadership and belonging rather than relying solely on authority or resources, while progressively developing participatory governance capabilities across the network. This paper extends theory on orchestration in inter-organizational networks, highlighting specific practices to strengthen the capacity of networks to meet increasingly complex societal needs.

Keywords: orchestration, coordination, grand challenges, collective action.

Introduction

Orchestration is a key mechanism through which organizations align actors, resources, and goals to achieve collective outcomes. It involves designing and managing inter-organizational relationships, establishing governance forms, and coordinating activities across multiple stakeholders to create value that no single actor could accomplish alone (Dhanaraj & Parkhe, 2006; Nambisan & Sawhney, 2011; Paquin & Howard-Grenville, 2013; Roehrich et al., 2023). Orchestration is therefore critical in complex settings, particularly when actors have divergent interests, unequal resources, and limited incentives to collaborate. Moreover, while orchestration is often examined in contexts where lead organizations hold formal authority and abundant resources, we know much less about how it unfolds under conditions of resource scarcity, limited authority, and conflicting priorities, conditions typical of grand challenges (Grabski-Walls & Ambos, 2024; Kalra & Roehrich, 2024; Krystallis et al., 2025; Leixnering et al., 2025).

Grand challenges are ambitious, complex problems that lack clearly defined solutions, are characterized by evolving requirements, and involve the participation of multiple actors across different fields and institutions (Churchman, 1967; Ferraro et al., 2015; Gehman et al., 2022). Addressing these societal problems, such as reducing poverty, developing health treatments, and mitigating climate change and other environmental crises, requires large-scale initiatives and collaborative efforts, which often give rise to additional organizational challenges that must be effectively managed (Brammer et al., 2019; Ferraro et al., 2015; Gümüsay et al., 2022b, 2022a). Such collaborative efforts often result in specific initiatives undertaken by multiple actors to achieve a common goal (Gehman et al., 2022; Rouyre et al., 2024). Consequently, the debate on grand challenges primarily emphasizes collaboration and cooperation rather than individual initiatives. In this context, policymakers, corporations, non-governmental organizations, and associations are examples of collective actors whose interactions within inter-organizational settings can advance progress on societal challenges (Angeli et al., 2022; Drori et al., 2025; George, Fewer, et al., 2024a; Leixnering et al., 2025).

In grand challenges, achieving progress largely depends on the orchestration of actors, activities, and resources required to achieve coordination across participants (George, Fewer, et al., 2024a; Gulati, Wohlgezogen, et al., 2012a; Leixnering et al., 2025; Reypens

et al., 2021). These activities are commonly conceptualized as collective actions, coordinated behaviors by multiple actors to achieve a shared objective (George, Fewer, et al., 2024a; Olson, 1965; Ostrom, 1998). They require organizations to align perceived efficacy (Lee et al., 2017), develop common interests (Lee et al., 2017), establish authority (Davis, 2016), and mobilize resources and expertise (Taylor & Singleton, 1993). In such contexts, orchestration is typically carried out by "orchestrators", i.e., lead actors who, thanks to their central position, facilitate partner coordination, sustain collaboration, and guide interactions. They play a key role in establishing governance forms and aligning activities across diverse stakeholders, crucial to achieve coordination (Dhanaraj & Parkhe, 2006; N. Oliveira & Lumineau, 2017; Roehrich et al., 2023). Such lead actors or lead organizations are particularly important in collaborative networks that demand centralized authority, stability, and the investment of resources to create value for all the participants (Berthod et al., 2017; Krystallis et al., 2025; Provan et al., 2007; Reypens et al., 2021). Their role is especially challenging in the context of grand challenges, where these characteristics are often absent. In fact, given the unpredictable and unconventional nature of grand challenges, lead organizations are required to address tensions and conflicts that may arise from such multi-actor collaborations (Cao & Lumineau, 2015; Krystallis et al., 2025; Roehrich et al., 2023, 2024). In these contexts, lead organizations are not always able to exert authority and mobilize resources required to orchestrate collaborative initiatives, particularly in their early stages (Brammer et al., 2019; Drori et al., 2025; Ika & Munro, 2022; Leixnering et al., 2025). Therefore, understanding how inter-organizational collaborations are orchestrated in the context of grand challenges addresses an important gap in the literature.

Prior research offers limited theoretical insights into the factors that ensure effective orchestration in inter-organizational settings characterized by a high level of complexity, such as grand challenges (Dhanaraj & Parkhe, 2006; Hurmelinna-Laukkanen & Satu Nätti, 2018; Reypens et al., 2021). This gap is particularly salient, as orchestration is more commonly achieved when strong authority, adequate financial means, and necessary resources are available. Here, lead organizations may struggle to provide resources or exert authority, which hinders their ability to gain legitimacy and orchestrate collective action (Bridoux & Stoelhorst, 2022b; Drori et al., 2025; Kapucu & Beaudet, 2020; Lee et al., 2017). In this paper, we investigate how lead organizations orchestrate a network of

diverse actors to enable collective action under conditions of limited authority and resources. In particular, we explore how they foster goal consensus, support novel activities, and mitigate tensions from conflicting priorities and different interpretations, which are typical of grand challenges scenarios (Couture et al., 2023; Gray & Purdy, 2018; Grodal & O'Mahony, 2017). Despite recent advances in dynamic approaches to governance, little is known about how lead organizations can build trust and initiate progress within the early phases of grand challenges initiatives, where authority, power, and resources are often limited (Drori et al., 2025; Krystallis et al., 2025; Leixnering et al., 2025; Olson, 1965).

To explore these dynamics empirically, we examine the Italian implementation of the European '*LIFE Bear-Smart Corridors'* (BSC) initiative, part of a broader project conducted across eleven countries. This setting offers a unique context for studying inter-organizational relationships in response to grand challenges. The BSC is a multi-actor project that aims to create '*Bear Smart Communities',* a model designed to achieve multiple objectives: facilitating the coexistence between humans and wildlife; ensuring the survival of the unique species of the Marsican brown bear; supporting nature-based enterprises; raising awareness about the importance of biodiversity and nature in the Central Apennines. We focus on the initiative's early stages, characterized by limited resources and the need to establish trust among diverse stakeholders. Therefore, in regard to this initiative, we ask: *How do lead organizations orchestrate inter-organizational networks to overcome coordination challenges and sustain collective action in response to grand challenges?* To address this question, we developed a case study based on a grounded theory approach (Gioia et al., 2013). Our analysis draws on qualitative data collected over 18 months, including ethnographic observations, semi-structured interviews, and archival sources. We make the following contributions. First, we illustrate that network orchestration in grand challenges contexts unfolds through three key strategies: *setting up network leadership*, *building network legitimacy*, and *scaffolding network governance*. These strategies enable lead organizations to sustain collective action in settings where relying solely on authority or resources may not be sufficient (Bridoux & Stoelhorst, 2022b; Kornberger et al., 2025). Second, we argue that orchestrators must leverage collective leadership and a shared sense of belonging while supporting the development of bottom-up participatory governance capabilities across the

network (Grabski-Walls & Ambos, 2024; Krystallis et al., 2025; Roehrich et al., 2023). Third, this paper extends theory on orchestration in inter-organizational networks, highlighting the dynamic and recursive practices that strengthen the capacity of networks to meet increasingly complex societal needs, thereby contributing to the theoretical discourse on the impact of organizations on social systems (Mair & Seelos, 2021; Stern & Barley, 1996).

The remainder of the paper is structured as follows: firstly, we introduce the literature on orchestration, inter-organizational collaboration, and grand challenges to provide the background of the study. Next, we outline the methodology, detailing our empirical context, data collection, and analysis protocol. Finally, we present our findings and discuss how our insights contribute to existing literature.

Literature Review

Inter-organizational coordination and the role of orchestrators

Managing inter-organizational collaborations requires the coordination of multiple independent actors, each with distinct interests and objectives, whose actions are intrinsically interdependent and extend beyond unilateral control (Ashkenas et al., 2015; Gray et al., 2000; Gulati, Wohlgezogen, et al., 2012a). Collaboration can be understood in terms of two distinguished facets: cooperation, defined as '*joint pursuit of agreed-on goals'* grounded on a shared understanding of contributions and payoff (Gulati, Wohlgezogen, et al., 2012b) and coordination as the '*deliberate and orderly alignment*' of activities to achieve collective objectives (Gulati, Wohlgezogen, et al., 2012b). Among collaborative activities, coordination refers to the effective alignment and adjustment of partners' actions, crucial for the success of strategic alliances (Gulati, Wohlgezogen, et al., 2012a). Achieving coordination, however, is challenging as collaborative actors often embody different and sometimes conflicting logics. These actors typically include businesses, governments, non-governmental organizations, and other stakeholders, each bringing different perspectives, while concerned with specific problem domains (Gray et al., 2000; Gulati, Wohlgezogen, et al., 2012a; Phillips et al., 2000a). Examples of such relationships can be found in the grand challenges literature. In their study on field

mobilization, Grodal and O'Mahony (2017) investigated how scientists, governments, providers, and entrepreneurs, despite diverging interests, mobilized resources to advance molecular manufacturing in nanotechnology. Couture et al. (2023) examined how businesses, governments, and non-profit organizations addressed degrading water health and overcame coordination challenges through a multi-stakeholder initiative.

Coordination has long represented a central concern in management literature, tracing its roots to classical organizational theory. Foundational contributions by Herbert Simon, James G. March, and Thomas W. Malone reflected on how actors can collaborate harmoniously and the challenges that arise from these interactions. March & Simon (1958) emphasized the importance of managing interdependencies among organizational tasks to reduce uncertainty and enhance collective performance. These interdependencies, combined with incomplete information (reflecting bounded rationality), conflicting objectives, and organizational rigidities, may lead to coordination challenges (Simon, 1991). Such challenges may be addressed by identifying and characterizing the coordination processes involved. These include the allocation of shared resources, the management of relationships among actors through participatory design, and the decomposition of tasks resulting from the selection of shared goals (Malone & Crowston, 1990, 1994).

More recently, scholars have advanced the literature on inter-organizational coordination and contributed to the debate by elaborating on governance forms, structures, roles, and mechanisms that facilitate coordination. Accordingly, the achievement of coordination depends on the selection and interplay of these elements, which can interact in combination to shape members' relationships across the network (Abbott et al., 2016; N. Oliveira & Lumineau, 2017; Roehrich et al., 2023, 2024). Network orchestration refers to the process of managing such elements by creating connections and legitimacy, establishing collaborative structures, and advancing progress to collective objectives (Dhanaraj & Parkhe, 2006; Paquin & Howard-Grenville, 2013; Reypens et al., 2021). For example, inter-organizational projects are commonly conducted by a network of actors with varying degrees of specialization, whose activities must remain coherent and aligned with a shared goal (N. Oliveira & Lumineau, 2017; Roehrich et al., 2023). In these settings, the orchestrators are actors who play a crucial role in shaping governance structures, leveraging shared resources, and fostering new partnerships while aligning

with common objectives (Manning, 2017; N. Oliveira & Lumineau, 2017; Roehrich et al., 2024). Network orchestrators are actors who, due to their central position, guide interactions, align efforts, and sustain collaboration among diverse partners by facilitating actions needed to create and access assets and resources (Dhanaraj & Parkhe, 2006; N. Oliveira & Lumineau, 2017; Roehrich et al., 2023).

Despite growing interest in orchestration practices across various inter-organizational domains, such as public-private partnerships, strategic alliances, and large inter-organizational projects, it is only recently that scholars have begun to explore orchestration practices across organizations addressing broad societal challenges (George, Fewer, et al., 2024b; Gulati, Wohlgezogen, et al., 2012a; N. Oliveira & Lumineau, 2017; Roehrich et al., 2024). As orchestration entails establishing the network, attracting participants, and investing substantial resources to support members' objectives (Paquin & Howard-Grenville, 2013; Roehrich et al., 2023), grand challenges settings may introduce additional complexities. Initiatives in these settings, particularly in their early phases, are often characterized by ambiguous objectives, limited resources, and a lack of shared commitment (Ferraro et al., 2015; Ferraro & Beunza, 2019). Therefore, there is a call for a better understanding of orchestration and governance of collaborative initiatives and collective action, particularly in contexts marked by complexity, resource scarcity, and limited authority (Ferraro et al., 2015; George, Fewer, et al., 2024a; Leixnering et al., 2025).

Orchestrating grand challenges: Governance forms and coordination

Addressing grand challenges requires collaboration among multiple independent actors, whose collective efforts are essential to tackling societal problems beyond the scope of any single organization (Ferraro et al., 2015; Howard-Grenville & Spengler, 2022). These global issues are defined as "*formulations of global problems that can be plausibly addressed through coordinated and collaborative effort"* (George et al., 2016). Inspired by the UN Agenda 2030, research on grand challenges is undergoing a renewed wave of interest, with scholars from diverse disciplines seeking to advance solutions to pressing societal issues, ranging from poverty reduction and the developments of health treatments to climate change mitigation and environmental safeguarding (Ferraro et al., 2015; Gehman et al., 2022; George et al., 2016; Gümüsay et al., 2022b). Tackling these urgent

societal needs requires bold ideas and novel approaches that combine actions, knowledge, and resources from multiple actors (Ferraro et al., 2015; A. J. Porter et al., 2020). These challenges resist conventional approaches because they lack clearly defined solutions, follow non-linear dynamics, and involve the participation of multiple, independent actors across different fields and institutions (Churchman, 1967; Ferraro et al., 2015; Gehman et al., 2022). Therefore, advancing progress for grand challenges largely depends on the orchestration of actors, activities, and resources required to achieve coordination and enable collective action (George, Fewer, et al., 2024a; Gulati, Wohlgezogen, et al., 2012a; Leixnering et al., 2025; Reypens et al., 2021).

Collective action refers to coordinated behaviors by multiple actors to achieve a shared objective (George, Fewer, et al., 2024a; Olson, 1965; Ostrom, 1998). Organizations enabling collective action must align perceived efficacy (Lee et al., 2017), foster common interests (Lee et al., 2017), establish authority (Davis, 2016), and mobilize resources and expertise (Taylor & Singleton, 1993). Collective action emerged as a promising approach to promote large-scale collaborative initiatives, due to its nature (Ferraro et al., 2015; Ostrom, 2000). Building on the collective nature of grand challenges, Ferraro (2015) introduced the concept of robust action, articulated through three strategies: *participatory architecture, multivocal inscription, and distributed experimentation*. Participatory architecture refers to creating spaces, such as platforms, virtual environments, or physical locations, where actors can interact. These actors must be multivocal, meaning that they participate with differing and sometimes conflicting perspectives and evaluative criteria. Multivocality, in turn, allows for distributed experimentation, enabling the design and implementation of alternative, innovative, bottom-up solutions in localized initiatives (Ferraro et al., 2015; Gehman et al., 2022). Therefore, as a result of their evaluative nature, reaching a shared consensus on these challenges proves to be difficult to achieve (Ferraro et al., 2015). In such contexts, orchestrators can be crucial actors as they are capable of facilitating the coordination of these actors, supporting their relationships, integrating resources, and establishing governance forms to support coordination (Dhanaraj & Parkhe, 2006; Grabski-Walls & Ambos, 2024; Krystallis et al., 2025).

Existing research has examined orchestration from multiple perspectives, highlighting how coordination occurs in inter-organizational networks through formal and informal organizational structures (Roehrich et al., 2023), contractual, relational, and other

governance arrangements (Cao & Lumineau, 2015; Roehrich et al., 2023), and several approaches to decision-making (Provan et al., 2007; Reypens et al., 2021). Selecting the appropriate strategies and governance forms is crucial to effectively coordinate collective action in inter-organizational networks. Management research distinguished between shared and lead governance arrangements (Paquin & Howard-Grenville, 2013; Provan et al., 2007; Reypens et al., 2021). In shared-organization governance, members collectively coordinate activities, are flexible in decision-making, and have high levels of trust (Provan et al., 2007; Reypens et al., 2021). While this form is more appropriate to strengthen consensus and legitimacy that are already established, lead-organization governance is more effective in novel settings, where activities have not yet gained legitimacy and consensus has not been established (Paquin & Howard-Grenville, 2013). Lead-organization governance is particularly important in collaborative networks that demand centralized authority, resources, and stability (Berthod et al., 2017; Krystallis et al., 2025; Provan et al., 2007; Reypens et al., 2021). The role of lead organizations involves providing substantial resources for collaboration (Levén et al., 2014; Reypens et al., 2021), facilitating partner interactions by creating spaces for engagement (Paquin & Howard-Grenville, 2013), balancing network stability and flexibility (Berthod et al., 2017; Manning, 2017), and building legitimacy and trust (Abbott et al., 2016; Berthod et al., 2017; Gulati & Gargiulo, 1999). These studies suggest that governance forms are established in the initial phases (Provan et al., 2007; Roehrich et al., 2023) and subsequently coordinated (Grandori, 1997; N. Oliveira & Lumineau, 2017). However, more recent contributions argue that governance can be reconfigured over time, particularly in long-term settings where network composition and activities evolve (Krystallis et al., 2025; Rouyre et al., 2024). Such reconfigurations have proven particularly effective in strategic alliances, innovation ecosystems, and other networked arrangements that advance projects or address grand challenges (Brusoni & Prencipe, 2013; George, Fewer, et al., 2024a; Gil & Fu, 2022; Gulati, Wohlgezogen, et al., 2012a). Yet, despite these advancements, our understanding of orchestration in grand challenges initiatives remains limited. Due to their intersectoral, multivocal, and experimental nature, a poorly orchestrated network or governance obstacles can compromise collaboration and lead to collective action and coordination failures, which may erode the actors' ability to address grand challenges (Couture et al., 2023).

Collective action and coordination problems in grand challenges

Selecting appropriate governance forms for orchestrating grand challenges is essential, as they can facilitate actions, resolve conflicts, and support the sharing of resources and expertise (Bridoux & Stoelhorst, 2022b; Leixnering et al., 2025; Tannir et al., 2024), thereby influencing network interactions and collective action (Couture et al., 2023; Gehman et al., 2022; Rosca et al., 2022). Conversely, poorly orchestrated networks or governance obstacles can lead to collective action problems and coordination failures (Couture et al., 2023; George, Chaturvedi, et al., 2024; Jarvenpaa & Välikangas, 2016; Krystallis et al., 2025). Despite empirical evidence on the reliability and effectiveness of lead organizations in complex scenarios (Berthod et al., 2017; Moynihan, 2008), with roles that include providing resources for collaboration (Levén et al., 2014; Reypens et al., 2021), creating spaces for engagement (Paquin & Howard-Grenville, 2013), and building legitimacy and trust (Abbott et al., 2016; Berthod et al., 2017; Gulati & Gargiulo, 1999), grand challenge settings can significantly expose the network to unforeseen coordination problems.

Coordination problems emerge when conflicting interests, intentions' uncertainty, or a lack of communication lead to inefficiencies in achieving collective goals. Such problems may arise due to the presence of coordination costs associated with the complexity of the context, or because organizations may encounter difficulties in allocating the shared values among their stakeholders or to society at large (George, Fewer, et al., 2024b). Other causes include information and communication gaps among actors involved in achieving a shared goal (George, Fewer, et al., 2024b). For example, in their study on organizational resilience, Van Der Vegt et al. (2015) explored the challenges of managing risk in the case of unpredictable and disruptive events. In doing so, they highlighted the coordination challenges that arise among organizations, networks, and stakeholders. Similarly, the study by Falcke et al. (2024) on coordinated innovation in response to climate change examines how multiple for-profit organizations address coordination problems by realigning their value propositions in joint efforts. As a result, coordination challenges can create conflicts and tensions, threaten the effectiveness of inter-organizational collaboration, and ultimately undermine collective action. On the other hand, collective action problems emerge when actors experience tensions between their *short-term* self-interest and the *long-term* collective interest (Bridoux & Stoelhorst, 2022b; Olson, 1965).

They often emerge in situations where actors can have negative consequences, for example, when some individual efforts are not directly rewarded but exclusively create positive outcomes for the collectivity (Bridoux & Stoelhorst, 2022b). Such problems originate, for instance, from actors' low perceived efficacy (Lee et al., 2017), diverging goals and interests (Lee et al., 2017), lacking trust (Davis, 2016), and differences in resources, expertise, and input within a network (Taylor & Singleton, 1993).

Addressing coordination failures requires orchestrators to provide substantial resources to achieve collective outcomes, such as managing information sharing, providing spaces for engagements, sharing activities, and decision-making (Krystallis et al., 2025; Tannir et al., 2024). Similarly, addressing collective action problems requires organizations to adopt complex, multilayered mechanisms of coordination, collaboration, and communication (Klein et al., 2019; Ostrom, 2000). Lead organizations play a key role in preventing these problems and supporting collaborative networks (Klein et al., 2019; Kornberger et al., 2025; Krystallis et al., 2025) as they must define formal and informal coordination mechanisms and governance forms to foster effective actor mobilization, alignment of activities, and the sharing of information (Reypens et al., 2021; Roehrich et al., 2023). While empirical evidence suggests that shared governance is suitable in strengthening already established consensus and legitimacy, lead governance is particularly useful in novel networks, where decisions and activities still require legitimization (Berthod et al., 2017; Kalra & Roehrich, 2024; Krystallis et al., 2025; Paquin & Howard-Grenville, 2013). They are crucial in initiating goal consensus and legitimizing novel activities while mitigating tensions and conflicts. Effective orchestration and proper governance forms can therefore mitigate diverging priorities, conflicting interpretations, and power asymmetries in order to sustain long-term network stability (Couture et al., 2023; Gray & Purdy, 2018; Grodal & O'Mahony, 2017). However, how lead organizations prevent these problems and provide substantial resources and mechanisms to address conflicts within long-term initiatives remains poorly understood (Cao & Lumineau, 2015; Krystallis et al., 2025; Roehrich et al., 2023, 2024).

Despite growing evidence on the role of lead organizations in addressing coordination failures, little is known about how they can build legitimacy and initiate progress within grand challenges settings. In these settings, heterogeneous actors with diverging

perspectives and from different institutional fields must collaborate and therefore must align around a common outcome (Conteh, 2013; Grabski-Walls & Ambos, 2024; Tannir et al., 2024). Moreover, the literature commonly assumes that orchestration and coordination are more easily achieved when authority, financial means, and resources are available (Roehrich et al., 2020; Tannir et al., 2024; Zhong et al., 2017). For example, in exploring the dynamics of inter-organizational collaboration, Philips et. al. (2000) showed that partner organizations benefit from a backdrop of established resources and practices from institutional fields, which facilitate coordination and the exercise of influence, particularly when power relations are defined. More recently, Olsen et al. (2016) further highlighted the importance of legitimacy in multi-stakeholder initiatives to generate potential innovative solutions. Similarly, Reypens et al. (2021) emphasized the importance of legitimizing authority in orchestration practices to achieve stakeholder consensus. However, while lead organizations are crucial to ensure substantial resources and network stability, the unpredictable and unconventional nature of grand challenges may hinder their ability to exert authority or mobilize resources required to orchestrate collaborative initiatives, particularly in their early stages (Brammer et al., 2019; Drori et al., 2025; Ika & Munro, 2022; Leixnering et al., 2025). Scarce resources and limited authority can generate interpretive, structural, and relational issues, including different interpretations of a common problem, financial instabilities, and power asymmetries (Couture et al., 2023). Despite these potential shortcomings, few studies have explored how lead organizations orchestrate under such conditions (Couture et al., 2023; Divito De Paauw et al., 2019; Krystallis et al., 2025; Voegtlin et al., 2022).

In summary, although prior research has examined how inter-organizational collaboration is established, led, and orchestrated, a key theoretical gap remains in understanding how orchestration unfolds when lead organizations lack formal authority, decision-making power, or substantial resources. Most existing studies implicitly assume that successful orchestration depends on these structural levers; however, such conditions are often absent in grand challenge settings (Dhanaraj & Parkhe, 2006; Hurmelinna-Laukkanen & Satu Nätti, 2018; Reypens et al., 2021). These contexts are marked by volatility, resource scarcity, and actor heterogeneity, where conventional coordination mechanisms tend to break down and the risk of collective action failure increases. This creates a fundamental tension between the assumptions of orchestration theory and the realities of practice in

grand challenges contexts. Despite the growing relevance of this problem, we still know little about how lead organizations establish legitimacy, mobilize actors, and sustain coordination under such constraints (Bridoux & Stoelhorst, 2022; Drori et al., 2025; Kapucu & Beaudet, 2020).

Research Setting and Method

Our empirical context is represented by the *LIFE Bear-Smart Corridor project (BSC),* an environmental safeguarding initiative taking place in central Italy that aims to create and promote a model of '*coexistence'* between humans and wildlife. Advancing coexistence means fostering harmony among species, protecting natural ecosystems, and ensuring their accessibility while preventing exploitation and harm. It requires collaboration among a variety of actors. These actors include public organizations, national parks, NGOs, local enterprises, municipalities, and residents, thereby forming a complex collaborative network pursuing the shared objective of environmental and wildlife protection. We conducted a longitudinal case study (Eisenhardt, 1989) to investigate how local lead organizations orchestrated the formation of an inter-organizational network in a grand challenges setting, initially characterized by a collective authority yet to be established, limited resources, and therefore the need for legitimation. Our study focuses on two years of the BSC project and provides rich insight into the behaviors and interactions of the actors involved, as well as the coordination processes and the governance mechanisms across the collaborative network.

Research Setting: The project LIFE Bear-Smart Corridors

In 2021, Rewilding Europe, a European environmental conservation foundation, began selecting key areas across the continent to develop a network of pioneers capable of implementing coexistence measures and advancing environmental conservation. Eleven extensive landscapes across eleven countries were identified, along with lead pioneers called upon to develop autonomously large-scale projects in order to deliver benefits for both nature and local communities, while promoting the adoption of rewilding principles throughout Europe. Despite initial funding and a relatively solid background, these pioneers initiated a challenging path marked by multiple obstacles, including, for

example, developing and initiating entirely novel practices, engaging diverse stakeholders, fostering disruptive behaviors, implementing innovative technologies, and simultaneously attempting to curb old, unsustainable practices. All these practices shaped a context in which these pioneers were required to build trust and legitimacy among stakeholders, despite operating with limited resources.

Our investigation focuses on the Italian implementation of rewilding principles, specifically in the Central Apennines, where a group of lead organizations agreed to collaborate to conduct the BSC project. The BSC promotes the development of multiple initiatives, among which are *Bear Smart Communities* and *Coexistence Corridors*, models fostering the coexistence between humans and wildlife across Europe through coordinated efforts. These efforts aim to ensure the coexistence between humans and wildlife and ensure the survival of unique and endangered species living across the continent. Examples include creating safe habitats for wildlife through concrete actions, supporting nature-based enterprises, achieving relations and support of a multitude of stakeholders, and raising awareness for enabling both people and wildlife to thrive together. The lead actors emphasized fostering cooperation among local communities, supporting nature-based enterprises, and enhancing the positive impact of visitors and tourists. They operate in an extensive area located in the Central Apennines, a region characterized by natural habitats of great complexity and a deep relationship with humans and their activities. This region is one of the most significant and extensive natural systems in the country, characterized by a significant diversity of animal and plant species worthy of conservation. Known for its exceptional biodiversity, the Apennines are protected by the highest concentration of parks and reserves in Europe. Above all, this region is the house of the Marsican brown bear, a unique, endemic species, which has become a beloved and iconic symbol of the nation's natural heritage and wildlife, representing the importance of biodiversity and natural ecosystems.

The BSC operates within a global scenario where natural ecosystems, critical sources of food, clean air, and water, and habitat for countless species, are threatened by human activities and climate change. Such pressures, including mass tourism and deforestation, disrupt ecosystems, endanger biodiversity, and expose millions of species to the risk of extinction. Addressing these challenges is urgent and essential, as ecosystems support the economic, ecological, recreational, cultural, and scientific dimensions of human lives. In

line with the Sustainable Development Goals, fostering responsible human activities and engaging local communities becomes crucial to sustaining healthy ecosystems and promoting human well-being (United Nations, 2015). The Central Apennines wildlife is characterized by exceptional biodiversity and a high share of protected areas, where wildlife share their living spaces with human settlements and associated activities. This ecological and social interdependence creates a distinctive context of coexistence, but also inherent tensions. Such spaces are also inhabited by the Marsican brown bear, which, despite its elusive and solitary nature, may occasionally encounter human settlements in search of food or habitat, leading to potential conflicts, perceived threats, and safety concerns for both humans and animals. These rare but high-stakes encounters exemplify the fragile balance of coexistence in human-wildlife interfaces and require careful management through a range of initiatives, such as wildlife monitoring, the development of wildlife corridors, and local education programs on coexistence. Moreover, these initiatives necessitate the involvement of multiple actors and collaboration across diverse fields to develop solutions, but this heterogeneity can lead to diverging perspectives, tensions, and potentially conflicts.

Actors involved in the *LIFE Bear-Smart Corridors* project

The BSC project involves a variety of actors from multiple institutional fields across central Italy. Among these, three lead organizations emerge as orchestrators of the initiative: the National Park of Abruzzo, Lazio and Molise (*Parco Nazionale d'Abruzzo, Lazio e Molis*e – PNALM), Rewilding Apennines (RA), and *Salviamo l'Orso* (SLO). Together with several local and non-local partners, they committed to advancing approaches to environmental conservation through multiple initiatives such as *Bear-Smart Communities* and *Coexistence Corridors*, with the goal of developing and scaling these efforts across European countries while promoting the sustainable development of their territories.

PNALM is the oldest national park in Italy and one of the richest in biodiversity. Besides the Marsican bear, the park is home to the endemic Apennine chamois, the Apennine wolf, the deer, and the golden eagle. Together with many other species, they contribute to an exceptional biodiversity. Over the years, PNALM has managed the complex wildlife of central Italy through dedicated activities such as monitoring and surveillance, conducting

scientific research, and promoting the adoption of best practices to encourage positive coexistence with wildlife. The park emphasizes the importance of fostering communities capable of living in harmony with nature but recognizes the need to extend its values and norms to the broader society, beyond the park's boundaries, to effectively address this ambition. PNALM sustains that a growing number of actors must adopt values, norms, and behaviors aligned with the preservation of nature to ensure long-term positive relationships between humans and wildlife.

RA is an association of the Rewilding Europe Foundation, part of a larger network of organizations throughout Europe, engaged in innovative strategies for nature conservation. Their primary aim is to protect and restore the natural functioning of ecosystems. Their commitment also includes promoting ecosystem restoration, encouraging people to positively coexist with wildlife, and supporting sustainable, nature-based enterprises. To achieve this mission, their efforts focus on several areas, including field operations such as monitoring activities or equipment installations, raising environmental awareness among local stakeholders, and promoting the development of alternative forms of tourism and business models without exploiting natural resources.

SLO is a volunteer-led nonprofit organization committed to preserving and promoting the expansion of the Marsican brown bear population in the Central Apennines. They are engaged in projects to improve the bear's habitat by making it safer, enhancing food sources, and improving humans' awareness of wildlife, as well as supporting ecotourism.

The main challenges faced by these organizations stem from the characteristics of the territories, including the heterogeneity of the communities, a complex network of actors, and the novelty of the initiatives undertaken, which together complicate the orchestration of collective action. The BSC project unfolds through local-scale efforts that are set up in rural regions in the Central Apennines, characterized by scarce resources, numerous small local enterprises, and actors often resistant to change. Despite the presence of the national park, many activities were unprecedented, with frequent and dispersed experimentations that made legitimation both necessary and difficult. Similar challenges emerged in coordinating the diverse actors involved, as the BSC required developing strategies that incorporate multiple perspectives, organizing meetings to strengthen the network, and engaging stakeholders in decision-making and strategy development. These dynamics

resonate with the principles of participatory architecture, multivocal inscription, and distributed experimentation, which are typical of grand challenges research (George et al., 2016; Howard-Grenville & Spengler, 2022). In line with these principles, the lead organizations engaged a network of actors capable of contributing to the advancement of the BSC. The following table 19 illustrates the actors involved and highlights their institutional roles, interests, and orientations toward coexistence.

TABLE 19 List of involved actors in the BSC project

Actor	Role	Focus	Orientation
National Parks	Institutional and regulatory authority	Biodiversity protection, conservation of natural resources	Regulatory, conservation-oriented
Local municipalities	Local governance and policymakers	Territorial planning, regulations	Administrative, policy-oriented
NGOs and Environmental organizations	Voluntary associations	Biodiversity protection, ecosystem restoration	Non-profit, environmental-oriented
Local Enterprises	For-profit local businesses (SMEs, start-ups)	Economic growth, local development	Market, profit-oriented
Local Communities	Residents and social groups	Livelihoods, land use, resource access	Socio-cultural-oriented
Researchers and Scientists	Academic and research actors	Knowledge generation, biodiversity monitoring	Scientific, knowledge-oriented
Tourist Operators	Service providers in the tourism sector	Development of tourism experiences	Economic, service-oriented
Tourists and Volunteers	Visitors and temporary contributors	Recreation, engagement in conservation	Individual, experience-oriented
External Partners	Collaborating organizations	Partnership building, project implementation	Cooperative, network-oriented

Lead organizations orchestrated and coordinated this inter-organizational network, engaged the diverse actors and stakeholders, and advanced innovative collective strategies for environmental safeguarding. To do so, these organizations coordinated institutions, residents, entrepreneurs, and non-governmental organizations (NGOs), many of whom typically lack opportunities to interact, collaborate, and confront a shared

objective. Through the BSC, these actors became part of a global environmental challenge, gaining the opportunity to represent their roles and advance their needs by participating in the discussions, sharing ideas, and contributing to nature preservation and sustainable development for the welfare of all. Orchestrators needed to actively engage with network members to set up interaction spaces, mediate relationships among the involved actors, manage collaborative activities, and overcome obstacles, while addressing coordination problems, criticisms, and doubts, gradually gaining legitimacy and trust. Such potential collective action failures, often arising from tensions among diverse stakeholders, underscore the crucial role of the orchestrators in maintaining network cohesion and advancing the common mission.

Methodology

We conducted an in-depth case study based on a grounded theory approach to understand the role of network orchestrators in coordinating inter-organizational networks in response to grand challenges (Gioia et al., 2013; Strauss & Corbin, 1999). We collected qualitative data over 18 months, including ethnographic observations, semi-structured interviews, and archival sources. Our study began with the collection of archival documents and an initial round of interviews. Subsequently, we received permission to observe and actively participate in activities by volunteering with two of the lead organizations we identified (PNALM and RA). During this period, we collected detailed field notes and conducted additional interviews with participants.

Data collection

Data collection relied on multiple sources, including secondary data, open-ended interviews with members participating in the initiatives, and, finally, participatory observations, which also comprised a second round of more in-depth interviews. Data collection spanned 18 months, beginning with secondary data collection in May 2023 and concluding with the final interview in April 2025, and it is articulated in 5 phases. A graphical representation is reported in Appendix a. This comprehensive approach enabled us to collect rich, insightful data, offering an inside view of the organizations conducting

the initiative and their role within the surrounding community in the context of grand challenges. Table 20 summarizes our data sources.

TABLE 20 PNALM, RA and SLO data sources

PNALM Data source	**Phase**	**Details**
Archival Data	· Preliminary	· Appendix a
Open-ended Interviews	· 1 step	· 16 open-ended interviews
Ethnography	· Participant observations · Final interviews	· Fieldnotes · 8 open-ended interviews

RA Data source	**Phase**	**Details**
Archival Data	· Preliminary	Appendix a
Open-ended Interviews	· 1 step	9 open-ended interviews
Ethnography	· Participant observations	Fieldnotes

SLO Data source	**Phase**	**Details**
Archival Data	· Preliminary	Appendix a
Open-ended Interviews	· 1 step	1 open-ended interview
Open-ended Interviews (*non-direct*)	· Multiple steps	Third-party insights from partners

Secondary data. In the first stage of the study, we collected archival and public documents. This archival material covered articles and significant reports published on the topic. Specifically, we gathered various types of secondary data, such as annual and scientific reports, articles, newspapers, posts, scientific studies, and datasets, to compile valuable information from multiple sources. These materials served as an archival database for our analysis phase. From this data set, we sampled documents for qualitative

analysis, conducted in the second stage of analysis. Furthermore, this archival research provided the essential background knowledge, allowing us to approach the subsequent stage of data collection concerning interviews in a more informed and targeted manner. Additional information is available upon request.

Interviews. In the second stage of data collection, we conducted a preliminary literature review to structure our questionnaire and carried out a document analysis to provide background context, thereby enabling us to conduct the interviews more effectively. We then carried out the first of two rounds of interviews, encompassing four phases, ranging from July 2023 to April 2025. This round included 24 open-ended interviews with PNALM members representing diverse roles and backgrounds, including the director, managers, rangers, biologists, and external stakeholders. The interviewees varied in their level of experience within the organization and with the initiative, ranging from central members such as organizers to individuals in diverse stakeholder roles. We then conducted 9 interviews with RA and collected important insights to better inform our inter-organizational perspective, and 1 interview with SLO, alongside information that emerged from interviews with members of partner organizations and other secondary data sources.

In total, these interviews span 13 hours and 47 minutes with PNALM, 6 hours and 2 minutes with RA, and 35 minutes with SLO (see Table 20 for an overview and detailed information). The interviews were guided by a structured protocol that covered topics such as roles, activities, and initiatives, collaborations, strategies, and relationships. All the interviews were recorded, transcribed, and coded to identify relevant themes, supporting the development of the case study. Details of the interviews are reported in Appendix b.

Participant observations. One of the authors has been directly involved in the activities on two occasions: with PNALM within the volunteer program for eight days and with RA engaged in a monitoring operation. First, the PNALM Director granted us permission to participate in the organization's activities as volunteers for a period of eight days. During this period, the author engaged directly in daily operations, collecting detailed field notes as an active member. Second, the RA Team Leader allowed the author to participate in the activity as a volunteer. These participatory observations allowed us to gather rich data

and gain a deeper understanding of the local context. The direct involvement provided valuable insights into the social dynamics and facilitated our connections with diverse stakeholders. During the ethnographic phase, we also conducted a second round of interviews with members and other stakeholders, completing a total of 8 interviews over 2 hours and 33 minutes with PNALM members (see Tables 20 and Appendix b for a detailed overview). These data were recorded in the form of field notes and expanded daily through the development of an out-of-the-field dictionary (Van Maanen, 1988; Walford, 2009). This approach enabled us to capture a comprehensive understanding of the organizational dynamics and the surrounding social context.

In the final step, we triangulated the data gathered from interviews with participant observations and archival data such as reports, policy documents, press documents, and news. This helped us to understand the relationships, resource sharing, power dynamics, and actions within and outside the lead organizations.

Coding protocol

Our analytical approach is based on grounded theory (Strauss & Corbin, 1999). We analyzed field notes, interview transcripts, and secondary data using an abductive theory-building approach. This approach revealed to be particularly effective in grand challenges studies, as Eisenhardt noted (2016, p.1113), they "*are likely to be essential for making progress on grand challenges*". Therefore, we began by isolating and examining our data sources to understand how the lead organizations enacted robust action principles to achieve collective action within the initiative. During this phase, we iterated between the emerging themes from our data and network orchestration literature, which allowed us to connect our inductive insights. The use of multiple data sources enabled us to triangulate across the data, thereby enhancing the reliability and robustness of our findings.

Data analysis

Our data analysis consists of two main phases: an initial document analysis to establish the background context and identify broad themes, followed by a content analysis, which forms the core of our exploration. Within the analysis, we also integrated the results from the document analysis to enhance the reliability and depth of our findings. The details of both the document and the content analysis are outlined in the following paragraphs.

Documental analysis. We developed conceptual categories based on the characteristics of each document. These initial conceptual categories facilitated navigating the extensive secondary data during the subsequent stages of our analysis. This first stage supported our work in two ways. First, it guided the development of the interview questionnaire, specifically informing the selection of the interviewees and the major topics to address. Second, it supported us in categorizing the other data for the second stage of data analysis, focusing on identifying the conceptual categories among the extensive data sources. In the subsequent stage, these documents were read and analyzed to identify relevant segments of text related to the phenomenon under exploration. These segments were then integrated into the content analysis and incorporated into the final data structure (Appendix b for the overview).

Content analysis. Data from interviews, observations, and secondary sources were coded through an iterative approach, which involved writing the case, coding and collecting additional data, and comparing emerging concepts with the literature. We began our content analysis after completing the ethnographic observation, carefully reviewing all the materials, including fieldnotes, interview transcripts, and secondary documents from the focal organizations. The coding process was supported by NVivo software, where we uploaded and organized the various data sources, including archives, interviews, and observation records. The core focus of our analysis was to investigate the key phenomena and the actors' relationships involved in addressing the local-scale challenge.

In the *initial stage* of content analysis, we developed an extensive list of codes to capture how the grand challenge was approached and how the coordination unfolded over the course of the initiative. Following the *Gioia methodology*, our coding process entailed two iterative steps (Gioia et al., 2013; Strauss & Corbin, 1999): the development of informant-centric 1st order codes (concepts) and theory-centric 2nd order codes (themes). This process allowed us to gradually shift from descriptive concepts of our empirical investigations towards academic-based themes, which are oriented to the findings of our paper. We systematically read each part of the transcriptions and secondary data, highlighted the most relevant themes, and coded them in NVivo by assigning them to nodes. We proceeded with refinement and regrouping of these nodes to identify further nodes and relationships. To enhance reliability, a coder was involved in the process and worked through continuous iterations between two researchers to incorporate multiple

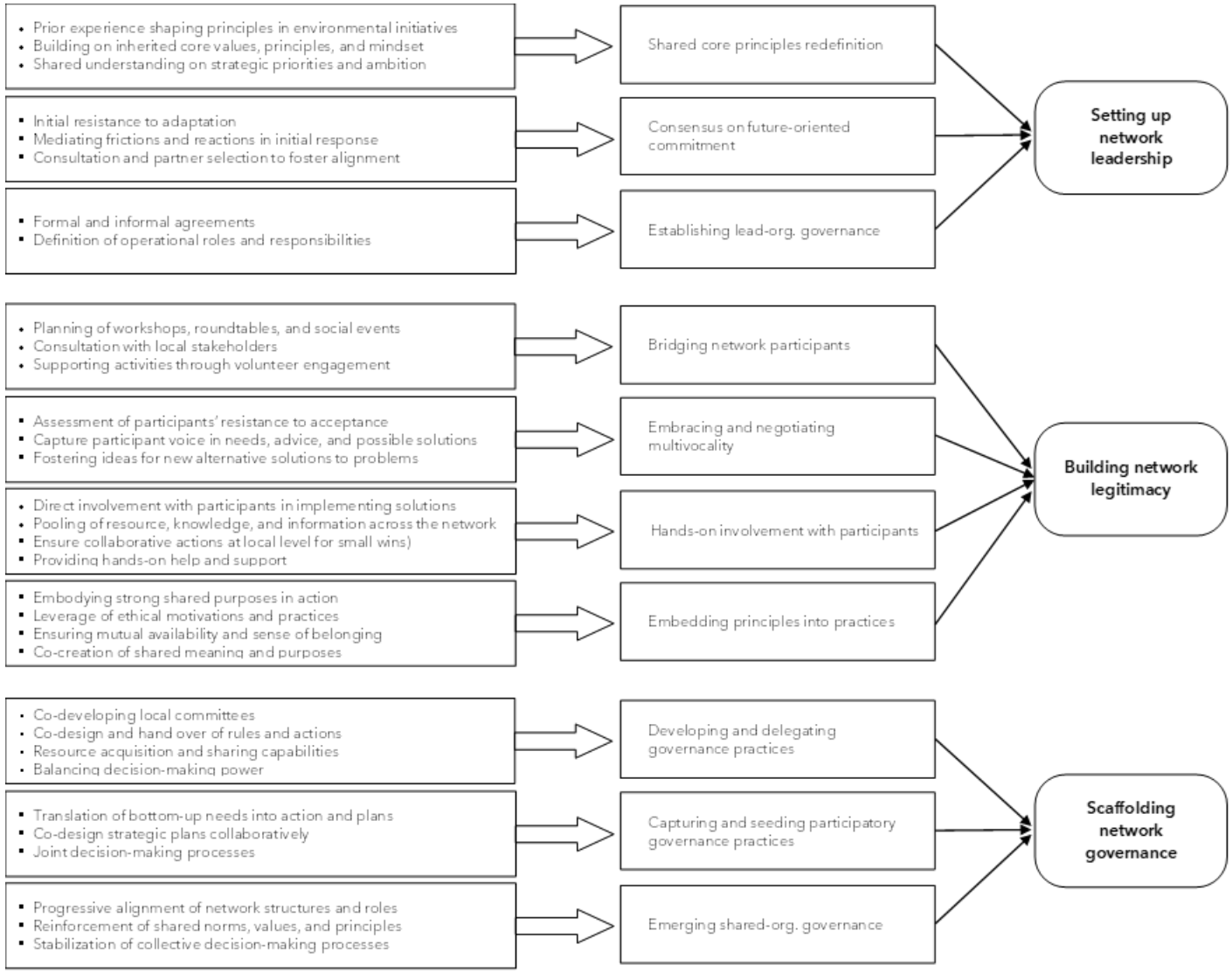
perspectives. For example, at the first-order level, we initially focused on identifying key activities and efforts conducted by the lead organizations related to legitimacy building within the network. Emergent concepts in this stage included, for example, "*Planning of workshops, roundtables, and social events"* and "*Consultation with local stakeholders*." We generated these first-order codes to assess the organization's efforts to engage and connect the diverse partners involved.

In the *second stage* of the content analysis, we iteratively engaged with our codes, the relevant literature, and the evolving draft of our data structure. This continuous process enabled us to develop the theoretical second-order themes. The literature on coordination (N. Oliveira & Lumineau, 2017), network orchestration (Roehrich et al., 2023), and grand challenges (Howard-Grenville, 2021) informed by this step, guiding us in identifying the role of the orchestrators in overcoming coordination obstacles and driving the network toward effective collective action. For example, an emergent theme at this stage was *"Bridging network participants*." We developed this second-order theme by grouping the first-order codes presented in the previous paragraph: "*Planning of workshops, roundtables, and social events"* and "*Consultation with local stakeholders*." This process grounded our data in the grand challenges literature, connecting robust action principles to the initiative under study. Relying on the same procedure, we identified additional themes related to the central role of lead organizations in fostering coordination and the impact of inter-organizational networks in grand challenges, representing our novel theoretical contribution to the literature.

In the *final stage*, we increased the level of abstraction by linking our emerging themes into aggregated dimensions. These dimensions capture the relationships among second-order themes and provide the foundation for our theoretical propositions, grounded in both respondents' insights and the literature. To ensure coherence, we iterated continuously between data, literature, and emerging dimensions. This process led to the refinement of the visual representation of our analysis, where the relevant first-order concepts, second-order themes, and their interconnections are represented. The aggregated dimensions constitute the building blocks of our emerging framework, firmly rooted in the data. The following section presents our findings, illustrating how these dimensions connect empirical insights and the broader theoretical framework. The

following Figure 8 presents our data structure, which outlines concepts, themes, categories, and relationships.

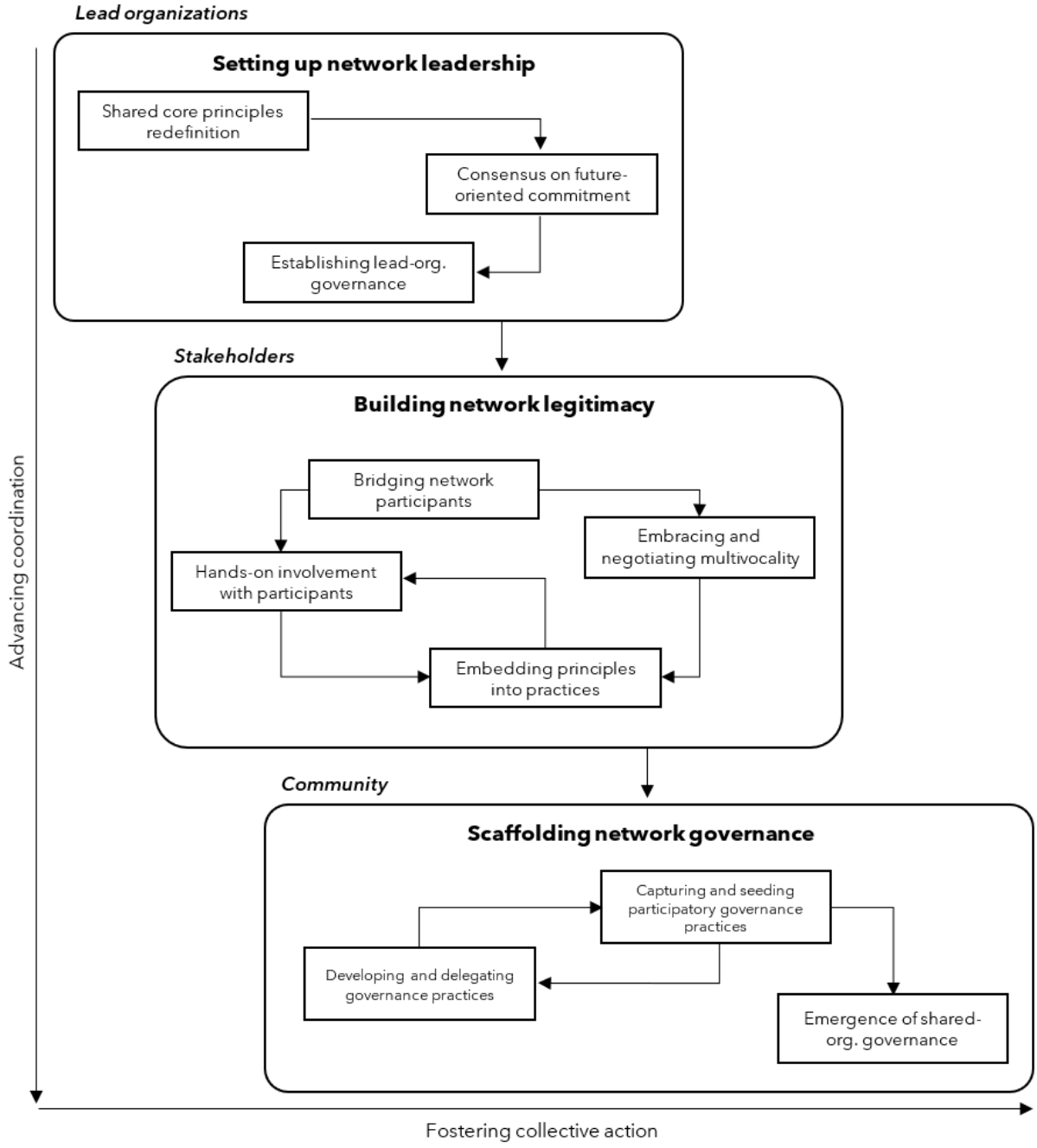
FIGURE 8 Data Structure – Network Orchestration for grand challenges



Findings

Our study investigates how the lead organizations orchestrate inter-organizational collaboration to overcome coordination challenges and foster collective action within the environmental safeguarding grand challenge initiative in central Italy. Figure 9 illustrates our conceptual model, which explains three interconnected phases of network orchestration in grand challenges settings.

FIGURE 9 Framework of Network Orchestration to foster Collective Action



Our analysis identified three interconnected phases of network orchestration in grand challenges, in resonance with robust action literature (Ferraro et al., 2015): setting up network leadership (i), building network legitimacy (ii), and scaffolding network governance (iii). We next discuss our findings following the overarching theoretical dimensions and outline them with the informant quotes supporting our statement.

Setting Up Network Leadership

On the 5ft of October 2013, the Central Apennines was designated as a Rewilding Landscape, encompassing extensive territories that include three National Parks, among which is the PNALM. Five years later, a working group known as Rewilding Apennines was established, defining both the scope and scale of this initiative. This establishment led to the formation of key local partnerships, which proved crucial to ensuring the long-term success of the BSC initiative. However, these collaborations did not emerge out of nowhere.

"*In 2011, Rewilding Europe was formed as a non-profit foundation and produced a call for applications that was joined by associations from different European countries to nominate areas to become rewilding areas."* – extract from Interview I RA

In the initial phase, RA, SLO, and PNALM took action to launch the initiative by establishing mutual collaboration and outlining a preliminary action plan. These organizations agreed to implement the BSC and to develop a set of initiatives aimed at fostering positive human-wildlife coexistence in Italy. They intended to form a steering group of key local stakeholders, such as municipalities and associations, to ensure comprehensive representation. Among this group, a few had already collaborated in past initiatives, which proved advantageous in terms of shared understanding of core values and principles. For instance, RA and SLO, by sharing overlapping operative areas and interests, had collaborated on various activities even prior to the BSC. The synergy between these two associations, RA and SLO, has continued over time. Despite differences in approach, their principles, mindsets, and values are rooted in this earlier collaboration.

"*I think the values are those of SLO, which was the association that created the core group."* – extract from Interview I RA

This understanding facilitated the achievement of consensus around a forward-looking commitment. SLO engaged local actors to work to establish a "*bear-friendly community"* aimed at developing a series of best practices to improve human-bear coexistence. They also initiated the volunteer program and gradually advanced their mission. Then, Rewilding joined the local scene when, in 2021, as part of the BSC project, they began to involve additional actors. However, not everyone was fully aligned with the planning. The group experienced differing operational paces and some response frictions. Despite such initial coordination challenges, they agreed on selecting and engaging partners to set up a collaborative network. As one interviewee stated:

"*SLO decided to start collaborating with the Reserve and the Municipality to establish a 'bear-friendly community. Over time, this initiative progressed year by year. Then, Rewilding joined in. In 2021, the Life project began with SLO, RA, PNALM, Gran Sasso and Sirente Velino Parks, as well as the Municipality of 'Pettorano sul Gizio', and other partners."* – extract from Interview I SLO

This partner selection process introduced diverse perspectives and response heterogeneity, yet it represented a crucial step toward establishing a cohesive network: *"The BSC initiative involved a broad partnership with various local stakeholders, including national parks, municipalities, and even Greek partners. For some stakeholders, this collaboration presented a challenge due to differing operational speeds… The initiative led toward a greater impact on change."* – extract from Interview I RA

This first phase of the BSC required partners to align their operational speed with the lead organizations and to reach a consensus on their diverging approaches. Crucial in this phase was achieving alignment with the lead organizations in order to direct their mission, establish collaborative agreements, and involve additional actors accordingly. While some synergies were inherited from past collaborations and new partnerships were still refining their consensus, lead organizations signed a Memorandum of Understanding (between RA and PNALM). Such a formal agreement settled a cooperation framework, critical in addressing some key challenges in the protection of the Marsican brown bear. This agreement set a long-term strategic commitment, a key phase that gradually shaped

operations and relationship dynamics among the lead organizations. The development of a strategic plan to direct future joint efforts and identify opportunities for collaboration led to the implementation of innovative solutions, co-creation of novel ideas, and collective engagement. By doing this, lead organizations became progressively representative of the nascent network, advancing the initiative. RA and SLO, despite their prior collaboration, renewed their mutual commitment to rewilding activities, thereby driving this leading group to become responsible for expanding the network and developing community capabilities.

"*The MoU paves the way for a very fruitful cooperation between RA, the local communities, and the Abruzzo National Park for a long period looking forward, with an agreed strategy that combines nature conservation and rewilding with business, jobs, and income in all the communities around the park."* – extract from Secondary Data CA00

"*SLO and RA, in their collaborative agreement, recognize the need to provide clarity for their collaboration to achieve the following goals: develop a common solutions-oriented approach to help address the changes taking place in the Central Apennine countryside, providing opportunities for rewilding, wildlife comeback and building nature-based economies, connecting modern society with wilder nature, and creating a larger interest and awareness in the Italian public about the challenging conservation situation in Italy, the ecological importance of natural processes, including keystone species, that shape the landscape.*" – extract from Secondary Data ARA2

Through the agreements, it became evident how the organizations progressively achieved a unified vision and assumed a leading position within the network. Within the BSC project, the lead organizations aligned their foundational values and incorporated them into a common frame to provide a solid direction for their joint efforts to safeguard wildlife and raise awareness in the communities. This represents a first step in which the lead organizations advanced initial coordination and established a lead-organizations governance form, crucial for steering the strategic direction of the emerging network toward alignment and shared purposes.

"*The rewilding team is now going to cooperate in several ways with the National Park authorities, for example, around wildlife monitoring, hunters' involvement, wildlife tourism development, surveillance, and communication work." – "We work together to*

engage and involve the local communities from the surrounding areas, which are included in the National Park buffer zone, in saving and bringing back the endangered Marsican brown bear." – extract from Interviews I, II, and VI RA

Building Network Legitimacy

Once the lead organizations reached a shared purpose through both formal and informal agreements, their priority was to involve additional local actors to ensure that every category was represented within the initiative. This was a critical phase for many reasons. First, the lead organizations encouraged new participants to meet, to identify potential partners, and to bridge connections. The aim was to engage more participants and expand the network to foster the co-creation of value, the development of a shared long-term vision, and the effective dissemination of the BSC core principles. To this end, they organized a series of events such as meetings, committees, workshops, and roundtables to connect the community and encourage engagement and collaboration. Second, this network expansion phase increased the heterogeneity of participants, leading to diverging standpoints. The lead organizations were therefore required to mediate emerging tensions, identifying points of convergence among participants, and build initial interactions and trust both with and between them. For example, as one interviewee noted:

"The aim is to demonstrate to them that coexistence is possible… The idea we are working with is that we need a healthy natural environment, taking into account the presence of everyone. People working there are a lot, even indirectly, and we moderate their presence. Everyone must benefit from nature, beyond those who come to mind, there are also tour operators, hiking guides, hoteliers, and so on, in a faster and more trivial way." – extract from Interview V

The lead organizations understood that building legitimacy in a nascent network in developing innovative approaches to environmental safeguarding would be a major challenge. Besides embracing multivocality and ensuring everyone was represented in community events, they understood the importance of direct involvement in the activities. Determining who will carry out the operations, what resources are needed, and who will be involved would not be enough to build strong legitimacy. Therefore, they did not hesitate to either coordinate and participate, even following operations on a case-by-case basis, sharing expertise, resources, and workforce. This helped them to increase trust,

awareness, and progressively build legitimacy. Many of the activities were also conducted with the support of external actors, such as volunteers engaged by the lead organizations who collaboratively shared their capabilities and resources to maximize impact.

"To increase coexistence, it is essential that all the stakeholders feel involved and enjoy improved living conditions. Giving them the opportunity to express themselves, considering their proposals, and understanding their role in Rewilding is very important to them." – extract from Interview VI RA

"You show them that there is someone there to give them an answer, we go and offer them a solution" – extract from Interview V RA

"It is necessary to involve local people who may have always carried out traditional activities... and they should be guided in carrying them out in a certain way, without discouraging them." – extract from Interview XXIV PNALM

PNALM, RA, and SLO had an active role in coordinating activities, connecting all the participants, and fostering the implementation of best practices for peaceful wildlife coexistence. However, given the innovativeness of operations and the heterogeneity of the participants, lead organizations were required to iteratively adjust approaches, embrace visions, and create a common purpose-driven narrative shared by the entire network. Narratives related to the importance of human-wildlife coexistence, biodiversity, and a sense of belonging were crucial to keep the network involved. Navigating these perspectives ensured long-term collaboration and sustained commitment from the actors, while also helping to reduce tensions. Embedding such principles into everyday operations strengthened trust and a sense of reciprocity among the network, creating a positive impact and fruitful collaboration. This further helped to engage new participants, such as volunteers from several European countries, resulting in an additional workforce and hands-on support. A strong shared purpose, ethical motivations, and mutual availability fostered a shared sense of belonging and enabled further co-creation of shared meaning and purposes.

"With the help of SLO volunteers and positive networking among the area's National Parks and nature reserves, we are building strong, trustful, enduring relationships with

local communities… Going forward, we will continue our work to support the ongoing recovery of these wonderful, iconic animals." – extract from Interview I

Finally, replicating successful operations was a key mechanism for achieving meaningful outcomes throughout the extensive territory. When a specific measure was experimented with in one area and yielded positive results, efforts were made to share the insights and knowledge gained with other organizations and participants, enabling broader application and impact. Organizations involved in replicating operations coordinated knowledge and information sharing, activity planning, task allocation, and structured meetings to ensure effective replication through implementation processes. These processes require continuous communication among partners, fostering a culture of openness, effective collaboration and teamwork, and a proactive approach to exchanging expertise and best practices.

"*If a measure is adopted in the PNALM, then it can be redone here too. It can also be done 30 km away, or 40 km away – We try to implement techniques and operations from another part of our landscape, aiming to achieve the same outcomes."* – extract from Interview V RA

Scaffolding network governance

In the final phase, the lead organizations played a key role in developing and establishing social arrangements, creating spaces for interactions and engaging network participants through roundtables, meetings, and committees. Their long-term aim was to foster these participants to learn collectively and make them capable of advancing autonomous coexistence measures within their communities. This autonomy was intended to translate into shared decision-making power in order to support the development of interdependent local governance structures. These structures would be composed of all BSC stakeholders, including public and private organizations, municipalities, local communities, and local entrepreneurs. In this way, these local governances could ensure all network members are actively represented in the decision-making processes.

"*Within the BSC, we aim to establish local governances to ensure that it's not just us, as NGOs or public institutions, doing the work. Instead, we seek to develop and empower this governance model as much as possible, ultimately giving the communities this tool,*

structured in a way that aligns with their needs, so they can use it and shape their own future." – extract from Interview VI RA

Despite still maintaining a leading position, these organizations pursued a strategy aimed at supporting the development of governance practices and capabilities, while fostering the emergence of bottom-up, participant-driven shared governance. This strategy functioned as a reinforcing mechanism, combining short-term top-down support from the leaders with the long-term emergence of bottom-up shared governance. It fostered collective engagement, with local enterprises and local communities increasingly participating and committing to sharing ideas, learn, and experiments through these novel forms of collaboration. Within these meetings, called *committees,* they progressively became more involved in co-developing plans to support local SMEs, advance alternative forms of "*nature-based economies"*, and promote eco-tourism.

"The goal of committees is to develop a coexistence plan involving the guidelines that communities decide to implement. Each plan will be personalized based on the main stakeholders in the community… The work we are doing is largely guided by us and other focal actors, but the ultimate goal is to gradually hand over responsibility to them, so they can become independent. In other words, it's not just about SLO and RA, but we are present as members of the committee, alongside everyone else, no longer in a guiding role, but as part of a group" – extract from Interview I SLO

"The committees include various stakeholders, such as hunters, farmers, etc., so there are these technical roundtables with other figures involved in tourism, biologists, and there is also talk of coexistence measures and poisoning." – extract from Interview VI

In conclusion, the active presence of representatives from the lead organizations ensured all participants were aligned and that everyone's perspectives were considered. They employed both active and passive forms of coordination, adapting to participants who engaged with varying levels of initiative. By dynamically adjusting their involvement depending on the activities, decisions, and specific issues, lead organizations encouraged the development of autonomy within the committees, progressively driving them toward independence. This process fostered a self-reinforcing mechanism between the short-term top-down guidance and long-term bottom-up deliberation. In the short term, lead organizations developed and delegated governance practices to provide direction and

structure, helping communities assume responsibility for future environmental safeguarding initiatives through collective learning. Over the long term, they fostered participatory governance practices from the bottom up, allowing emerging capabilities, new network ties, and evolving patterns of interdependencies to consolidate into a stable, shared organizational governance.

"We are creating this process now, working with communities at the basis, and it is perhaps the most important part. Because if you work on the environment, you just go and do it, but working with the community is something that probably takes decades. We are really only at the beginning!" – extract from Interview I SLO

In summary, the lead organizations orchestrate the network in the absence of formal authority or substantial resources by building on shared values, ethical commitments, and collective purpose. Through participatory processes grounded in direct involvement and multivocality, they developed trust and network legitimacy, thereby mobilizing a community driven by common principles rather than control. Once network and legitimacy were established, the lead organizations gradually fostered autonomy among participants and progressively stepped back, becoming part of a participatory governance system in which leadership was distributed and less centralized. Table 21 details how orchestration unfolded within the context under examination.

TABLE 21 Comparative Overview of Network Orchestration Forms

	Strong Orchestration	**Light Orchestration**
Orchestrators role	Leadership through authority and resources (or established reputation)	Emerging Leadership through shared vision and commitment
Governance form	Lead-organization governance	Shared-organization governance scaffolding
Coordination	Formal control, hierarchy, contracts	Consensus building, relational alignment, adaptive
Legitimation	Authority, control, reputation	Direct involvement, mediation of multivocality, bridging ties
Consensus	Low, controlled coherence	High, fostering plural voices
Dependency	Highly centralized (e.g., *hub-and-spoke*)	Highly distributed, interdependencies
Competencies	High individual, organizational expertise	Collaborative development & co-adaptation
Reconfiguration	Functional process (*solving coordination failure*)	Deliberate process (*strategic mechanism – participation & collective action*)

Contributions

Theoretical contributions

Prior research on coordination has largely emphasized the role of lead organizations in orchestrating inter-organizational networks in large projects and multistakeholder initiatives within grand challenges settings (Couture et al., 2023; George, Fewer, et al., 2024a; Grabski-Walls & Ambos, 2024; Krystallis et al., 2025; Rosca et al., 2022). While these studies commonly assume that inter-organizational networks are orchestrated by mobilizing financial, technological, and infrastructural resources and led through formal and informal authority, how orchestration occurs in contexts where authority and resources alone are insufficient remains overlooked. In this paper, we examine how orchestrators advance coordination and enable collective action by establishing

leadership, building legitimacy, and supporting network governance within an environmental safeguarding initiative addressing the grand challenge of nature preservation (Ferraro et al., 2015). Our research offers two key contributions to inter-organizational network studies in empirical settings embedded in grand challenges scenarios.

Contributions to network orchestration and network governance

While prior literature offers important insights into structuring and coordinating inter-organizational collaborations, empirical studies of network orchestration in grand challenges settings remain limited (Gulati, Puranam, et al., 2012; Gulati, Wohlgezogen, et al., 2012a; Manning, 2017; Roehrich et al., 2024). Most of these studies implicitly assume that lead organizations within inter-organizational networks can successfully orchestrate when they mobilize or provide to the network substantial resources and infrastructures, exert authority, and guide participants through deliberate and purposeful action. They often assume that orchestrators can leverage participants' complementary capabilities and coordinate their contributions (Dhanaraj & Parkhe, 2006; Hurmelinna-Laukkanen & Satu Nätti, 2018; Perks et al., 2017; Roehrich et al., 2023). Such assumptions imply that resources and authority are directly associated with effective orchestration capabilities. In contrast, orchestrators within grand challenge settings operate under different conditions. In such settings, network members exhibit multivocality, meaning that it is not guaranteed that they share the same path towards a common objective. Here, shared goals and a unified direction cannot be taken for granted. Moreover, activities are often novel and experimental, meaning that they often need to be legitimized. Therefore, the orchestrators can experience difficulties while relying on authority, even when they have the power to exert it.

Within grand challenges settings, inter-organizational networks cannot be effectively orchestrated solely through the mobilization of resources – financial, technical, and infrastructural – or the exercise of authority. Rather, network orchestration requires organizations capable of providing leadership initially, building legitimacy around novel or experimental activities grounded in shared principles, then progressively stepping back and fostering the emergence of a shared governance form. We introduce a new type of orchestration, which differs from the conventional definition as it contributes to the

network through distinct capabilities. Here, orchestrators contribute to network coordination by mobilizing distinct relational capabilities rather than financial or structural power. Characterized by limited material resources and weak formal authority, they foster collective leadership and a shared sense of belonging through common principles and a collective vision. They build network legitimacy by promoting direct involvement, encouraging multivocality, fostering resource sharing, and mediating new connections among participants. Through these mechanisms, they transform everyone's individual interests into a broader collective meaning system that aligns and integrates participants' diverse motivations. Furthermore, they are able to reconfigure and stabilize shared governance through the establishment of agreements, definition of roles, distributed responsibility, and collective decision-making.

Prior studies on network governance have considered governance either as a static, top-down decision (Kalra & Roehrich, 2024), or as a dynamic process that evolves over time (Krystallis et al., 2025). They further examined how governance evolves and adapts to dynamic environments to impact network performance (Gil & Fu, 2022; Krystallis et al., 2025). However, while network governance evolves (Gil & Fu, 2022; Krystallis et al., 2025), its reconfiguration remains primarily associated with network effectiveness and performance (Kalra & Roehrich, 2024). In contrast, our findings reveal that reconfiguration can also function as a strategic mechanism to broaden network participation, redistribute participants' responsibilities, and foster collective action in addressing common challenges. This strategic mechanism functions as a catalyst where the orchestrators manage a two-fold process: establishing governance structures and practices from the top down, while concurrently fostering the bottom-up emergence of shared governance over time. This increases the willingness to contribute to the common challenge and the sense of being represented. In grand challenge settings, orchestrators' influence derives not from hierarchical control or authority but from collective strength, the shared commitment and purpose generated within the network itself. This perspective opens a new stream into orchestration through collective strength, complementing and extending existing understandings of orchestration. We introduce the idea of light orchestration: rather than solely mobilizing financial and technical resources, it is grounded in establishing and reconfiguring leadership, legitimacy, and collective governance.

Contributions to grand challenges and collective action studies

Previous research on grand challenges has shown that effective orchestration may overcome coordination and collective action failures and lead toward a common objective (Couture et al., 2023; Falcke et al., 2024; Grabski-Walls & Ambos, 2024; Gray et al., 2022; Krystallis et al., 2025; Martí, 2018; Olsen et al., 2016; Rosca et al., 2022). However, how orchestrators effectively foster collective action remains unclear. Grand challenges initiatives typically involve a heterogeneous set of actors with diverse perspectives and priorities, leading to misalignment within the network between participants and orchestrators, which is a common source of coordination failures. Such misalignments can, in turn, lead network participants to disengage from the collective effort. It is therefore important to understand how orchestrators advance coordination and sustain collective action for explaining network effectiveness in these complex settings. Our research provides empirical evidence and enriches theoretical insights on the role of the network orchestrators in managing collective tensions commonly arising within grand challenges initiatives.

First, orchestrators must recognize the inherently participatory architecture of such initiatives. Unlike traditional initiatives, where participants are typically identified, selected, or involved in a voluntary manner, grand challenge networks comprise a heterogeneous mix of actors who collaborate to meet diverse needs (Dhanaraj & Parkhe, 2006). Some participants deliberately choose to engage through intentional decision, recognizing the need for change. Others become involved more organically due to geographical proximity, social embeddedness, or shared orientations toward an issue of concern. While previous literature identified the initial phase as partner identification and selection, our findings reveal that orchestrators must first establish a core network leadership, a small group of partners united by shared core principles and long-term commitment (Grabski-Walls & Ambos, 2024; Roehrich et al., 2023). This foundational leadership then becomes responsible for engaging, integrating, and realigning participants as the network's strategic orientation gradually takes shape. Therefore, effective orchestration in a grand challenge begins with purpose alignment and leadership formation, which then enables the inclusive engagement of broader participants.

Second, as the network expands to include a broader range of participants, multivocality increases. This diversity ensures members' sustained engagement, yet simultaneously amplifies potential tensions, misalignments, and conflicts as heterogeneity grows. While prior research on managing coordination and collective action problems remains fragmented, we suggest that orchestrators act as a mediator of plural voices rather than controlling coherence (Drori et al., 2025; Jarvenpaa & Välikangas, 2016; Kornberger et al., 2025; Krystallis et al., 2025). Specifically, orchestrators foster multivocality by bridging participants' connections and supporting the translation of emerging understanding into actionable solutions. Their mediating role shifts the orchestrator's focus from authority and coordination to legitimacy-building through interactions and direct participation. In grand challenges contexts, where experimental practices often lack initial legitimacy, orchestrators contribute by fostering the legitimation of experimentations through direct involvement, relational mediation, and novel network ties.

In conclusion, our findings advance theoretical insights into network orchestration, where leadership, legitimacy, and shared responsibilities substitute resource dominance and formal authority as key drivers of coordination in grand challenges networks.

Conclusions

The main theoretical aim of this paper was to advance the role of orchestrators in inter-organizational networks addressing grand challenges. We conceptualize orchestration as a collective, legitimacy-building process rather than a resource-driven mechanism (Dhanaraj & Parkhe, 2006; Ferraro et al., 2015; Gulati, Wohlgezogen, et al., 2012a; Olson, 1965). This enables distributed coordination and fosters collective action in contests characterized by uncertainty, pluralistic voices, and novel operations yet to be legitimized (Ferraro et al., 2015; Gehman et al., 2022).

Our study illustrates that the orchestration process unfolds into three interrelated mechanisms: establishing network leadership among a core group of committed actors, building network legitimacy through multivocal participations and new network ties, and scaffolding network governance, which enables the progressive emergence of shared

governance. Through these mechanisms, orchestrators overcome coordination and collective action problems not only by providing resources or exerting authority, but by nurturing shared meaning, legitimacy, and collective engagement (George, Fewer, et al., 2024a; Leixnering et al., 2025).

We introduce the idea of light orchestration, a type of orchestration where networks are not managed solely by mobilizing financial, technical, and infrastructural resources and authority but through establishing and reconfiguring leadership, legitimacy, and collective governance. Here, orchestrators with limited resources and authority create collective leadership through shared meaning and governance to broaden participation and foster collective action. They foster multivocality by bridging actors and translating diverse perspectives into shared understandings and actionable solutions.

Our study extends the orchestration literature by revealing governance reconfiguration as a strategic mechanism, a self-reinforcing process through which orchestrators temporarily provide governance practices and structures while enabling the long-term emergence of shared, participatory governance. This insight bridges research on network governance and collective action in grand challenges settings, emphasizing the role of scaffolding (Mair et al., 2016) as a means to empower communities and stabilize collective efforts toward systemic change. In conclusion, this study suggests that effectively addressing grand challenges requires moving beyond the traditional assumptions on network orchestration toward forms of orchestration that leverage collective strength, rooted in negotiated strategic direction, mutual legitimacy, and the capability to deliberate and act collectively.

Our study certainly has limitations that, in turn, offer a promising path for future research. Firstly, our paper focuses on a single case study, which may restrict the generalizability of the findings. Future work can replicate our findings in additional grand challenge domains, where network composition, impact scale, or institutional logics may differ. Secondly, the empirical scope can be broadened by incorporating multiple cases that encompass varying temporal and spatial scales, scopes, and levels of analysis (Seelos et al., 2023). Finally, this thesis embrace coordination and network perspectives in the study of GCs which define the boundaries of our contributions. Future research could further engage with science–policy–society interface debates in the context of GCs and

sustainability-related issues, moving toward the exploration of themes such as invisible work and boundary spanners. Exploring how these concepts interact with orchestration processes can be essential and can strongly shape inter-organizational relationships.

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PART III: Concluding Remarks

7. Conclusions

This doctoral thesis aimed to investigate how urgent societal problems, defined as grand challenges, can be addressed through collective efforts, in contexts where no single actor can advance solutions independently. In such contexts, collective action and collaborative efforts are crucial for enabling the development of effective responses to complex issues, such as climate change, poverty, access to resources, or environmental harms. Here, local-scale actors confront such challenges on a daily basis and engage in ongoing efforts to identify and implement solutions. Therefore, understanding how local-scale initiatives are enacted through multi-actor networks, in which organizations, resources, and communities are coordinated, is essential to advancing practical, sustainable solutions to these societal challenges. This guided us to explore how collaborative actors and organizations develop innovative approaches at a local scale to advance solutions to complex, broader problems. We observed collaborative efforts across three levels of analysis, interpersonal, organizational, and network levels, to understand how heterogeneous actors collectively face a specific local yet global-scale problem. Thereby, we specifically investigated coordination and orchestration practices across these three levels of analysis, given the participatory and multivocal characteristics of contexts where actors with diverging logics and from different institutional fields must collaborate for a shared outcome.

At the *interpersonal level* explored in the first paper, we shed light on how interpersonal interactions shape knowledge-sharing mechanisms within the dynamic work contexts of grand challenges. Although knowledge sharing has been widely studied in management research, its functioning in the contexts of grand challenges remains underexplored. This paper intends to develop a theoretical framework illustrating how knowledge is shared among collaborative actors engaged in unconventional, highly dynamic activities. Our findings reveal that interpersonal interactions constitute the core of knowledge-sharing processes.

By unpacking interactions through communication tools and activity domains, we show that face-to-face interactions, particularly during situational and critical activities, enable rich contextual and vicarious learning. In these moments, shared fieldwork becomes a space where meaning is co-constructed, and expertise is transferred organically in the form of explicit and tacit knowledge. Digital interactions, in contrast, primarily support reflective learning and the codification of explicit knowledge, facilitating information exchange. While explicit knowledge is largely formed through reflective, experimental, and contextual learning, tacit knowledge emerges most strongly from vicarious learning. Overall, this paper demonstrates that knowledge sharing, central to the interpersonal level of grand challenges, is not driven by formal processes but is deeply rooted in interpersonal interactions and is strongly affected by how these interactions unfold. These mechanisms enable continuous learning and support coordination in settings where uncertainty, urgency, and complexity characterize daily work.

At the *organizational level* that we examined in the second paper, we investigated how organizations coordinate actors and configure the data value chain in the settings of grand challenges. Yet we know little about the technical and organizational aspects within these contexts, even though scholars have recognized the fundamental importance of these aspects for decision-making and collective efforts. This paper aimed to advance a multidimensional perspective of the data value chain by uncovering how organizations integrate and coordinate organizational, technological, and physical elements to extract value from heterogeneous and distributed data.

Our findings reveal that organizations engaged in grand challenge settings rely on an integrated and collaborative configuration of the DVC, where field-based activities, digital systems, and organizational coordination mechanisms are tightly interconnected. By unpacking the data value chain, we show that each dimension must be carefully configured to shape data quality and actor role. While the technical dimension refers to all the steps of the data value chain, the organizational dimension emerges as a key integrator. It is characterized by coordination mechanisms such as task allocation, inter-unit collaboration, information-sharing routines, and real-time communication, thereby sustaining alignment across actors and activities. In general, this paper demonstrates that effective data value chain management depends on the capacity to orchestrate physical, technical, and organizational dimensions. In doing so, it contributes to data management

research by moving beyond the technical-centric perspective toward a more embedded approach for organizations facing grand challenges. These insights strengthen the link between data management studies and grand challenge literature, emphasizing the importance of configuring dimensions to extract value from data through seamless coordination, robust technological integration, and strong organizational arrangements as well as external collaboration and partnerships to support collective action in complex environments.

At the *network level* explored in the third paper, we investigated how orchestration unfolds within inter-organizational networks addressing grand challenges. We focused on how lead organizations foster coordination and sustain collective action despite limited authority, resources, and formal control, conditions that characterize urgent and complex problem settings. While recent research has examined orchestration in more conventional contexts, far less attention has been given to how orchestration occurs when network participants are heterogeneous, activities are experimental, and legitimacy is not yet established. Therefore, to address this gap, this paper develops a theoretical model explaining how lead organizations orchestrate inter-organizational networks to enable collective action under such complex conditions.

Our findings reveal that orchestration in grand challenge settings relies primarily on relational, participatory, and legitimacy-building practices rather than on hierarchical authority or the mobilization of substantial resources. We show that orchestrators establish an initial network leadership grounded in shared principles and long-term commitment, which provides an initial landmark for grand challenge initiatives. They then foster multivocal participation by connecting diverse actors, mediating tensions, and translating heterogeneous perspectives into actionable meanings. Through relational engagement and direct involvement in activities, orchestrators legitimize experimental activities and align around emerging shared objectives. Finally, they introduce temporal short-term support to enable the progressive emergence of participatory governance. Through this paper, we introduce the concept of light orchestration, a bottom-up orchestration form where networks are not managed solely by mobilizing resources and authority but through the construction and reconfiguration of collective meaning, legitimacy, and governance. These relational mechanisms support coordination and sustain collective action in addressing grand challenges.

Each of these three papers presents individual contributions, yet together they form a unique, coherent research that investigates a local-scale context of a broader grand challenge across three levels of analysis. Research design, data, findings, and contributions are indeed interconnected, with each study revealing and explaining phenomena specific to its reference level. The first, as an explorative study at the interpersonal level, lays the groundwork for the second paper, which addresses organizational challenges in managing processes. The third paper observes the phenomenon from the broadest perspective, uncovering the inter-organizational dynamics, yet highlighting the importance of understanding the internal dynamics within each organization. Collectively, this work provides a comprehensive analysis of coordination across the three levels, uncovering intra-organizational, technical, and inter-organizational challenges of multi-actor initiatives addressing societal issues. In conclusion, facing grand challenges requires organizations to develop and leverage a set of essential capabilities, resources, and knowledge, both context-specific and relational. They must develop a deep understanding of their operating environments and be able to attract and engage key actors who must provide feasible contributions to the shared aim. As grand challenges lack single solutions or prescriptive strategies, organizations must navigate them through collaborative networks, developing strategies by realigning perspectives, negotiating ideas, and coordinating actors to generate widespread impact. This lies at the core of orchestration for grand challenges, where emerging lead organizations are capable of designing and managing networks, inspiring participants, and bridging contributions to advance progress without relying on any form of hierarchical control.

Although this thesis provides a comprehensive analysis of coordination and orchestration across three levels, further research on collaborative efforts for grand challenges is still needed. The inherently complex and context-specific nature of grand challenges potentially makes each setting unique in characteristics, collaborative dynamics, and boundaries. Consequently, despite the robust insights discussed in this research, capturing additional conditions from other contexts may be essential to fully capture how collective action unfolds in other settings.

One limitation of this work lies in its exploratory research design. While the case studies allowed us to understand in-depth the phenomenon, they might constrain the

generalizability of the findings. Replicating these results in additional contexts would provide stronger evidence of their broader applicability and help to identify potential boundary conditions. Second, while the study focuses on three levels of analysis, it does not explicitly account for other potentially influential dimensions, such as political or cultural factors. Future research could build on this study by applying the multi-level research design that we developed in this work to other grand challenge domains, particularly those where actors, organizational fields, or initiatives differ significantly. This design can enrich our understanding of coordination and orchestration processes within varying contexts to better understand how collective action functions. By expanding research in these directions, scholars and practitioners can develop a more nuanced understanding of how to orchestrate complex initiatives throughout the interplay of actors, organizations, and inter-organizational networks in pressing societal challenges.

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9. Appendices

Appendix I: Thesis Structure

Research objective	Investigate how organizations coordinate multi-actor networks by aligning actors, resources, and communities across interpersonal, organizational, and network levels to sustain collective action and enable effective coordination in addressing complex societal challenges.
Research questions	***RQ1****: How do interpersonal interactions enable knowledge sharing within the dynamic work environments of grand challenges? How does learning unfold in such contexts?* ***RQ2****:How do organizations govern and coordinate the data value chain in grand challenge contexts characterized by heterogeneous, dispersed, and boundary-spanning data?* ***RQ3****: How do lead organizations orchestrate inter-organizational networks to overcome coordination challenges and sustain collective action in response to grand challenges?*
Theoretical background	***Main topic***: Grand Challenges ***Concepts***: Collaboration and Coordination, Collective Action, Network Orchestration
Conceptual Framework	**Multi-level study of collaboration and topic**: • *Individual*: Knowledge sharing • *Organizational*: Data value chain configuration • *Network*: Network Orchestration for Collective Action
Methodological approach	Constructivism, practical realism Abductive approach
Empirical context	Qualitative approach, case studies. ***Grand Challenge initiative***: environmental initiative in central Italy (*LIFE Bear-Smart Corridor projects*) aimed at fostering human–wildlife coexistence through multi-level coordinated efforts among parks, NGOs, public and private actors. Focus on protecting the wildlife population, promoting sustainable tourism, supporting local enterprises, and aligning communities to support long-term conservation and local social and economic development through collective action.
Data collection	Secondary data Open-ended interviews Participant observations
Robustness	Triangulation of primary and secondary data

Data analysis	Qualitative analysis Coding (*open, selective, axial* – through NVivo Software) Co-occurrences analysis Content analysis
Approach	Grounded Theory, Gioia Methodology
Main findings	• Interpersonal interactions as the primary knowledge sharing mechanism, enabling learning, across activities, supporting effective coordination • Organizations manage an integrated, multidimensional, and collaborative data value chain to enable effective collaborative data-driven solutions from dispersed data across multiple actors • Organizations orchestrate inter-organizational networks by establishing leadership, building legitimacy, and scaffolding governance to enable collective action and strengthen network capacity to meet complex societal needs
Limitations	Qualitative research design based on case studies

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Appendix IV: Overview of Research Outputs

Research outputs
(includes peer-reviewed, submitted, and manuscripts in preparation for submission)

- Santarelli L., Ceci F., Masciarelli F., On Knowledge Sharing in Dynamic Work Environments: Lessons Yet to Be Learned
  Submitted to: Journal of Knowledge Management Research and Practice – First round of review

- Santarelli L., Ceci F., Configuring the Data Value Chain for Grand Challenges: Actors and Dimensions of Data Governance
  Submitted to: Communications of the Association for Information Systems – First round of review

- Santarelli L., Ceci F., Davies, A., Collective Action in the Wild: Orchestrating for Grand Challenges in Inter-Organizational Contexts
  In preparation for submission to: Academy of Management Discoveries

Book chapters

- Santarelli, L. and Ceci, F. (*forthcoming*), "Data Governance per le Grand Challenges: Configurazione di Ruoli e Dimensioni della Catena del Valore dei Dati" in: Unpacking Data Ecosystem Governance: Dynamics, Complexity, and Practice

- Santarelli, L., and Ceci, F., (2025) "Configuration of the Data Value Chain: Reflections on the Digital and Analogue Dimensions" in: Technology-Driven Transformation: The Future of Work and Organizations, LNISO, Springer

Conference proceedings

- Santarelli, L., Ceci, F., Davies, A., "Coordinating Collective Action for Grand Challenges: Insights from Inter-Organizational Collaboration" (2025), WOA2025, ISBN 979-12-210-9700-9

- Santarelli, L., Ceci, F., "Managing the Data Value Chain Off-Site: Exploring Challenges along the Path" (2025), WOA 2025, ISBN 979-12-210-9700-9

- Santarelli L., Ceci F, Sgammotta M., "Data Value Chain and Data Ecosystem through digital and traditional tools" (2024), Sinergie 2024. ISBN 978-88-94-7136-5-7

- Santarelli L., Masciarelli F., "Knowledge sharing and learning: face-to-face and ICTs" (2024), Sinergie 2024. ISBN 978-88-94-7136-5-7

- Santarelli L., Ceci F, “Enhancing Learning Through Knowledge Sharing Between Face-To-Face and ICTs Interactions” (2024), EuroMed 2024. ISBN: 978-9925-628-01-8

Presentations in conferences

- Managing the Data Value Chain Off-Site: Exploring Challenges along the Path (with Federica Ceci):
  - presented at WOA 2025 Conference, Pescara, Italy
  - presented at Euram 2025, Firenze, Italy

- Collective Action in the Wild – Coordinating for Grand Challenges in Inter-Organizational Contexts (with Federica Ceci and Andrew Davies)
  - Presented at 23rd IECER Entrepreneurship Conference, 2025, Reykjavik, Iceland
  - presented at EGOS Conference 2025, Athens, Greece
  - presented at SMS Special Conference 2025, Palermo, Italy
  - presented at WOA 2025 Consortium, Pescara, Italy

- Enhancing Learning through Knowledge Sharing between Face-to-face and ICTs interactions (with Federica Ceci)
  - presented at EuroMed 2024, December 2024

- Exploring Challenges in the Configuration of the Data Value Chain (with Federica Ceci)
  - presented at ItAIS 2024 conference, Piacenza, Italy, October 2024

- Data Value Chain and Data Ecosystem through Digital and Traditional tools (with Federica Ceci and Marianna Sgammotta)
  - presented at Sinergie SIMA 2024, Parma, June 2024

- Knowledge sharing and Learning through Face-to-face and Digital Tools (with Federica Ceci)
  - presented at Sinergie SIMA 2024, Parma, June 2024

- Enhancing knowledge sharing through human and digital settings: Challenges of embracing data-driven technologies (with Francesca Masciarelli)
  - presented ItAIS 2023 Consortium, Torino, Italy, October 2023