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*Research*, part of a Special Feature on Seeds of Good Anthropocenes: Envisioning and Exploring Pathways toward Transformative Futures

# The seeds' substrate: a concept to understand how transformations toward Good Anthropocenes can be enabled

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ABSTRACT. The importance of connectedness in laying the ground for social-ecological transformations or in spreading new ideas and practices for transformation is increasingly recognized. However, the role of networks in supporting the emergence and growth of seeds (initiatives with the potential to positively shape the future) has not yet been comprehensively studied empirically. To this end, we introduce a novel concept, the seeds' substrate, to characterize: (1) the relationships among a network of seeds, (2) the support needed for seeds to appropriately scale and coalesce, and (3) the actors that enable and provide support. The seeds' substrate concept was theoretically informed and empirically derived by using a case study of an ongoing coalescing process. On this basis, we derived several categories and definitions for seeds interactions, types of support, and supporting actors that collectively constitute the seeds' substrate. Specifically, we identified seven types of interactions between seeds, nine types of support, and 14 different categories of supporting actors. Furthermore, we presented a multi-level network approach to analyze the seeds' substrate and test specific hypotheses within this modeling approach. By putting the seeds' substrate concept into practice in an ongoing coalescence process involving 11 seeds around the small-scale fisheries food system in Uruguay, we identified the network of seeds and the constellations of actors and interactions that preceded efforts to deliberately foster a seed coalition. This allowed us to anticipate synergies and conflicts and to identify key supporting actors that structure the seed substrate. In addition, we derived a comprehensive baseline against which to quantitatively compare the unfolding of the coalescence process over time. This paper contributes to filling a gap in the Seeds of Good Anthropocenes literature and unpacks a key but largely unexplored subprocess of its theory of change: the transition from periods of experimentation to periods of coalescence. We expect the seeds' substrate concept to be useful in a wide and diverse range of social-ecological contexts.

Key Words: *coalescence; seeds of Good Anthropocenes; small-scale fisheries; sustainability initiatives; networks; transformations*

## INTRODUCTION

Moving from the current unsustainable trajectory (the Anthropocene) to safer, more equitable, and ecologically diverse worlds (Good Anthropocenes) will require fundamental changes that radically depart from the current regime (Bennett et al. 2016, McPhearson et al. 2021, Rockström et al. 2023). Achieving such a vision will demand transformations of human-nature relationships across a variety of settings and sectors, involving changes in assumptions, values, cultures, and worldviews (Moore et al. 2014, McPhearson et al. 2021). Though radical and fundamental, transformations will draw on and build upon many elements or initiatives that are already in place and that currently offer glimpses of futures better aligned with considerations of social-ecological safety and justice (Bennett et al. 2016).

To leverage the potential of existing and promising elements as entry points for transformations, a concerted global project called the Seeds of Good Anthropocenes (SOGA; https://goodanthropocenes.net/) seeks to identify, systematize, and analyze innovations that have the potential to contribute to a better future globally (Bennett et al. 2016). The SOGA project highlights the role of initiatives in experimenting with novel social-ecological configurations, generating practical and contextualized solution-oriented knowledge, and fueling novel bottom-up visions to redirect unsustainable trajectories (Bennett et al. 2016, Pereira et al. 2018, 2021, Raudsepp-Hearne et al. 2020, Sellberg et al. 2020). Although these initiatives are referred to in different ways across research fields, such as grassroots innovations, social innovations, niche innovations, transition experiments, or sustainability initiatives (reviewed in Lam et al. 2020), within the SOGA project they are metaphorically referred to as "seeds" (Bennett et al. 2016).

After almost a decade since its inception, most of the research on SOGA has focused on two main areas: how seeds can inspire alternative visions of desirable futures (Cork et al. 2023) and the intrinsic characteristics of seeds that enhance their transformative potential (e.g., Tuckey et al. 2023, Vrettos et al. 2024). This potential refers to the features that can lead to significant, long-lasting outcomes. For example, Tuckey et al. (2023) suggested that learning, empowerment, and networking are key features that enhance the transformative potential of seeds across Africa and lead to successful outcomes. Similarly, Vrettos et al. (2024) delineated the constitutive elements of degrowth seeds' transformative capacity, including shared goals and visions, network building, empowerment and learning, democratic governance, and equitable flow of resources. On the other hand, Lam et al. (2022) explored the amplification mechanisms of food-related seeds in the Stockholm region to better understand their transformative impact on the local food system. Determining how and for whom a seed holds transformative potential or whether an outcome is successful (let alone transformative) is a difficult

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and value-laden task that is inevitably influenced by where one "sits in the system" and whether the outcomes challenge or reinforce their own interests (Andrachuk and Armitage 2015, Pereira et al. 2024).

Comparatively little research has been done to better understand the so-called "coalescing periods," when seeds coalesce around common interests or goals, and the contextual factors that can facilitate or hinder this process. We argue that the social fabric around seeds is as important as the seeds themselves in bringing about transformative change. This is because the coalescence of seeds does not occur in a vacuum, but in an intricate network of actors and relationships that may provide a favorable social structural and relational foundation, which we refer to here as the seeds' substrate. We argue that research on sustainability transformations in general, and the SOGA project in particular, would benefit from a better understanding of the two-way interaction between seeds and their substrate. To deliberately enact transformations, a stepping stone is to unravel the network of potential relationships between co-occurring seeds and to characterize the context that can support and grow this network, aligning innovations and shaping strategic alliances (i.e., types of support and supporting actors).

In social-ecological research, transformations toward sustainability are conceptualized as multi-level (i.e., niche/micro, regime/meso, landscape/macro) and multi-phase (i.e., preparation, transition, and consolidation) processes (Olsson et al. 2006, Moore et al. 2014). In this framework, phases are described as sequential and interlinked, although transformative processes on the ground may unfold with more complex dynamics, including phase overlap and reversal (Moore et al. 2014). In the preparatory phase, seeds play a fundamental role, as they can form the basis for deliberate bottom-up transformations, offering alternatives when the need for systemic change at the macro level is emergent (Pereira et al. 2018). Under these circumstances, coalitions may emerge through the mutual reinforcement of seeds, guided by similar concerns, contexts, agendas, values, and goals, but with distinct offerings that can possibly combine with other ideas or actors (Pereira et al. 2018). Theoretically, these coalitions generate momentum and conditions to build shared narratives and visions, forming "proto-regimes," i.e., loosely integrated systems that have the potential to consolidate at the regime level (Smith and Raven 2012, Lam et al. 2022). Despite its pivotal role in the theory of change of sustainability transformation, the process of emergence of coalitions of seeds (hereafter, coalescence process) is poorly understood.

To shed light on this, we introduce a novel concept, the seeds' substrate, for characterizing: (1) the nature of potential relationships between a network of seeds, (2) the conditions that seeds need to scale and coalesce appropriately, and (3) the actors and the tangible and intangible support they provide to enable these conditions. The development of the concept has been informed by theoretical elements and nourished with lessons learned from a case study of an ongoing coalescing process. The paper first introduces the concept of the seeds' substrate, describing the main components and providing elements and tools to unravel the relationships that underpin the social fabric in which the coalescing processes of the seeds can take place. Second, a real-life example of an intervention aimed at deliberately fostering a seed coalition in the small-scale fisheries food system of Uruguay is used to illustrate the concept. By putting the concept into practice, the possibilities and limitations of such a concept for representing and modeling a coalescing process are identified and discussed in the context of the case study, but useful lessons are drawn for further applications. Finally, the need for better consideration of relational processes in the collective scaling of seeds and the possible ways to further unpack the seeds' substrate concept are discussed.

## THE SEEDS' SUBSTRATE: A DESCRIPTIVE-ANALYTICAL CONCEPT

In its basic definition, a seed is a vehicle for reproduction, containing the information and nutrition reserves within a protective shell to potentially produce another organism. But to spread, emerge, and thrive, seeds may need wind, rain, animal action, and other elements and strategies to maximize seed dispersal and survival, but most importantly, seeds need a suitable substrate. To account for all those factors beyond the intrinsic transformative potential of the seeds themselves, while using an analogous metaphor, we introduce a descriptive-analytical method to account for the relational nature of the coalescing process: the seeds' substrate.

The concept presented below is based on relevant elements of the literature on sustainability transformation (e.g., Moore et al. 2014, Pereira et al. 2018, Lam et al. 2020), as well as empirically derived and illustrated by a concrete case study on local food system transformation. The seeds' substrate concept is described from the bottom up, starting with the potential relationships between seeds, moving to the support they need to emerge and grow, and finally to the actors that provide support. Although we describe each component in a different subsection, all components are closely connected and must be conceptualized as a single unit.

### A network of seeds

In introducing the concept of seeds, Bennett et al. (2016) suggested that: (1) relationships between seeds can be positive, negative, or neutral; (2) seeds often form networks; and (3) location or place of emergence may shape the trajectory and values that underpin seeds. Subsequent research has portrayed seeds as isolated, niche experiments (e.g., Pereira et al. 2021), and some studies have looked at seeds on a continental or global scale (e.g., Jiménez-Aceituno et al. 2020, Tuckey et al. 2023), overlooking the role of location in configuring seed relationships. A significant amount of research has compiled and/or brought together seeds from a particular country or region to envision alternatives to current challenges and develop place-based desirable futures (e.g., Hamann et al. 2020, Sellberg et al. 2020, Pereira et al. 2022, van Velden et al. 2023), demonstrating a growing interest in the contextual specificities in which seeds coexist, but still overlooking the social fabric around seeds. In further developing seeds scaling processes (i.e., scale-out, up, and deep), Lam et al. (2020, 2021, 2022) exemplified and illustrated potential seeds relationships through amplification mechanisms, particularly those aimed at "amplifying out," highlighting the "legacy effects" that one seed, even after a long period of inactivity, can have on other seeds. More recently, Vrettos et al. (2024) emphasized the importance of networking for degrowth-related seeds to establish themselves and form mutual support

**Table 1.** Potential relationships between co-occurring seeds at the niche level. The sign indicates whether the relationship is potentially positive (+) or negative (-) for a coalescence process.

| Seed relationships | Definition | Supporting references |
|---|---|---|
| Cooperation (+) | The range of actions or activities that seeds might jointly undertake to achieve common goals. Actions may include but are not limited to: (1) developing project proposals, campaigns, and applying for funding or sponsorship; (2) implementing projects together (e.g., organizing workshops, creating development strategies or plans); (3) working together to change policies (e.g., through joint lobbying, coalitions or joint petitions and legislative proposals); (4) working together to establish new collaborations with other organizations or actors; and (5) building counter-hegemonic alternative networks. | Bodin et al. (2020), Lam et al. (2022), Felici and Mazzocchi (2022), Vrettos et al. (2024) |
| Flow of resources (+) | The sharing of tangible and intangible resources between seeds without commercial or financial purposes. Tangible resources include tools, equipment, materials, and facilities. Intangible resources include the exchange of information (by e-mail, telephone, or face-to-face) or informal advice on decision-making. | Lam et al. (2022), Felici and Mazzocchi (2022), Vrattos et al. (2024) |
| Coordination (+) | The consultation between seeds to implement actions, strategies, and/or campaigns without overlapping and thus avoiding competition or conflict. | Felici and Mazzocchi (2022) |
| Legacy effect (+) | The transfer or spread, whether voluntary or not, of key elements, principles, and values to a newly emerging seed in a similar or dissimilar context. The legacy effect can continue regardless of the possibility of the original seed ceasing to exist. | Lam et al. (2020, 2022) |
| Control (-) | The supervision or control by one seed over the decision-making or use of resources by another seed. | Felici and Mazzocchi (2022) |
| Competition (-) | The competition between seeds for finite resources or operating niches. | Felici and Mazzocchi (2022) |
| Conflict (-) | Direct disagreements or confrontations between seeds. | Bodin et al. (2020), Felici and Mazzocchi (2022) |

networks with like-minded organizations. On the other hand, Felici and Mazzocchi (2022) emphasized territorialization to study niche-level initiatives (i.e., entities analogous to seeds), reconstructing the relational contexts and demonstrating the key role of embedded territorial dynamics in fostering sustainable transitions.

In light of this, a key component of the seeds' substrate is the set of co-occurring seeds in a defined space and time as well as their relationships with each other, i.e., a network of seeds. Based on the review of recent papers on SOGA (e.g., Lam et al. 2020, 2022, Felici and Mazzocchi 2022, Vrettos et al. 2024) and our analysis of the case study, we have collated and defined a set of potential positive (i.e., cooperation, flow of resources, coordination, legacy effect) and negative (i.e., control, competition, conflict) relationships between seeds that may facilitate or hinder a coalescence process (Table 1). We recognize that these relationships are not mutually exclusive (e.g., a seed may cooperate with another seed on a specific action while having competing interests on other issues) and may be dynamic as seeds interact over time. For example, prolonged competition may lead to direct conflict. Conversely, coordination of actions and sharing of resources may lead to long-term cooperation. Although positive relationships are more likely to foster a social fabric conducive to coalescence, conflict can have constructive potential if approached with a constructive confrontation approach, meaning that a positive outcome is possible from a negative interaction.

**Support to scale and coalesce appropriately**

Another key component of the seeds' substrate is given by the supportive relationships between seeds and actors that provide some kind of support. Support is often conceptualized as the access to a valuable resource (e.g., Hanlon and Saunders 2007). However, we deliberately broadened the definition of "support" as the act of providing a seed with tangible or intangible, formal or informal, and informational, instrumental, or emotional assistance, backing, or encouragement. Thus, support can range from purely convenience-based (i.e., where compensation is expected) to value-based, where like-minded actors and seeds do not expect reciprocity. Note that we refer to support rather than resources to explicitly emphasize the relational context in which seeds and other actors interact, which includes relationships beyond those mediated by physical assets or tangible resources.

By combining elements from the entrepreneurship literature (e.g., Hanlon and Saunders 2007, Klyver et al. 2018) with the case study analysis, we identified and iteratively refined enabling conditions into nine types of support (Table 2): (1) advice, (2) network contacts, (3) sounding board, (4) financial support, (5) emotional support, (6) in-kind support, (7) legitimacy and reputation, (8) dissemination, and (9) training or capacity building. Other types of support that did not fit into any of these categories may include labor or prices below market value, commercial support and loyalty, and strategic information not generally available to the public. We also differentiated support into tangible (e.g., equipment, funding) or intangible (e.g., advice, contacts) and informational (e.g., sounding board) or instrumental (e.g., in-kind) types of support.

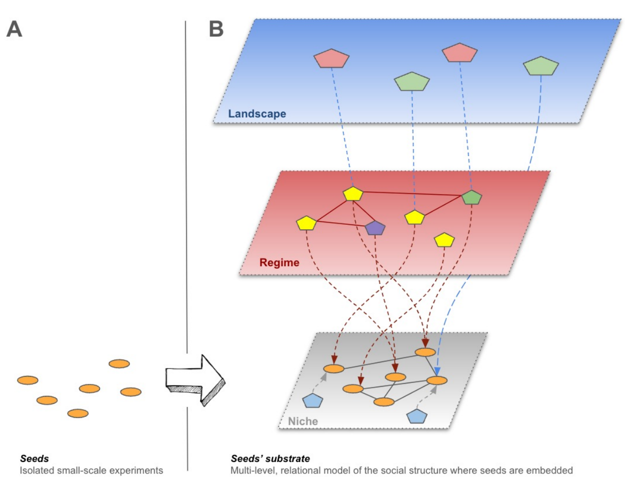
**Supporting actors**

Certain actors also form an important aspect of the seed substrate as they provide the support necessary to build the enabling conditions. Because of the broad definition of support adopted, we conceptualized supporting actors as more than just "resource providers" but as any social actor (e.g., individuals, communities, or organizations) that willingly provide assistance, backing, or encouragement. Therefore, supporting actors can range from friends, family, or community members providing support at the niche level to international organizations providing support at the macro level. Supporting actors can be differentiated between specialists (those who provide specific types of support) and generalists (those who provide diverse types of support). This distinction between specialists and generalists can be captured by using an index that simultaneously accounts for the amount and type of support received from a given supporting actor (Hanlon and Saunders 2007). Interactions or relationships among supporting actors are possible. For example, regime-level actors (e.g., a local government) can broker support from the landscape level (e.g., a foreign donor), for example, by channeling funds.

**Table 2.** Types of support that are often provided to seeds by supporting actors.

| Support | Definition | Characteristics | Supporting references |
|---|---|---|---|
| Advice | Support in the form of expert, technical, or professional advice, provided voluntarily or on a compensation basis. | Informational; intangible or soft | Hanlon and Saunders (2007) |
| Network contacts | Support in the form of valuable network contacts, provided voluntarily for seed emergence or scaling. | Informational; intangible or soft; instrumental | Hanlon and Saunders (2007) |
| Sounding board | Support provided by a person or group whose reactions to new ideas or products from a seed are used as a test of their validity or likely success | Informational; intangible or soft | Hanlon and Saunders (2007) |
| Financial assistance | Support from a financial institution, a donor, or an individual to the seed in the form of non-refundable support (e.g., grants allocated on a competitive basis or by allotment), refundable loan either at market or non-market conditions, or personal loan, etc. | Tangible; instrumental | Hanlon and Saunders (2007) |
| Emotional support | Support in the form of encouragement, empathy, closeness, familiarity, etc. It plays an essential role as a negativity buffer, fostering seed resilience in early stages and during crises. | Intangible or soft, instrumental | Hanlon and Saunders (2007), Klyver et al. (2018) |
| In-kind | Support in the form of goods or services provided to the seed at no cost, and/or trading goods or services between two or more parties without the use of money—or any monetary medium. | Tangible or intangible; instrumental | |
| Legitimacy and reputation | Support in the form of labels (e.g., sustainability, human rights, fair trade), membership, or seeds' self-reinforcement, provided or granted by an external entity whose actions and values are perceived or assumed as desirable or appropriate within a context-specific socially constructed system of norms, beliefs, and values. | Intangible or soft | Suchman (1995:574) |
| Dissemination | Support in the form of sales referrals, word-of-mouth promotion, broadcasting, and press, to the seed at no cost. | Tangible or intangible | Hanlon and Saunders (2007) |
| Training or capacity building | Support in the form of developing and strengthening the skills, abilities, processes, and resources that seeds need to flourish, persist, adapt, and thrive. Training may be formal or informal. | Tangible | Vretos et al. (2024) |

**Fig. 1.** (A) Seeds (orange circles) as deterritorialized, isolated experiments. (B) The seeds' substrate is a conceptual and relational model that links seeds (orange circles) with each other and with supporting actors (colored pentagon) at multiple levels.




They can also partner with other regime-supporting actors (e.g., the national government) to provide coordinated support (e.g., a partnership between two or more organizations to provide complementary support; Fig. 1).

By combining the review of the literature and the analysis of our case study, we identified 14 types of supporting actors (Table 3): (1) friend or family, (2) member or employee, (3) customer or beneficiary, (4) supplier, (5) professional advisor, (6) financial institution, (7) civil society organization, (8) grassroots movement, (9) educational or research centers, (10) national donors, (11) international donors, (12) local governments, (13) national government, and (14) private sector. Although supporting actors can occur at different levels (i.e., niche, regime, landscape), they mostly operate from the regime level.

**Putting the components together: the seeds' substrate**

The networks of seeds, the enabling conditions given by the support that seeds receive, and the constellation of supporting actors at different levels form the seeds' substrate (Fig. 1). Thus, the seeds' substrate is conceptualized as a multi-level relational model, where seeds interact at the niche level and supporting actors provide diverse support from the niche, regime, and landscape levels. The seeds' substrate represents the foundation wherein seeds can align and grow to become more transformative. As such, we expect the seeds' substrate to be dynamic and fluid, adapting to the needs and opportunities of coalescing processes. This substrate is also embedded in a broader context of social, political, economic, and environmental conditions that influence and shape the substrate and its development.

**Modeling the seeds' substrate**

Network approaches (Wasserman and Faust 1994) offer a suitable framework for empirically modeling relationships between co-occurring seeds and between seeds and supporting actors (i.e., support). This approach is based on the assumption that both relationships and attributes of seeds (e.g., characteristics such as site) and supporting actors (e.g., type of supporting actor) can be modeled and analyzed as social networks consisting of nodes (i.e., seeds, supporting actors) and links (i.e., relationships between them). Social networks can be modeled as one-level networks based on relationships between one type of node (seed-seed), or two-level networks based on relationships between two types of nodes (seed–supporting actor). Moreover, multi-level networks that include relationships within and across levels (seed-seed and seed–supporting actor) offer a holistic way to acknowledge and explicitly

**Table 3.** Actors who support seeds to emerge, stabilize, and thrive.

| Supporting actors | Definition | Level |
|---|---|---|
| Friend or family | The supporter has a personal or close relationship with individuals within the seed. | Niche |
| Member or employee | Individuals working or collaborating within the seed. | Niche |
| Customer or beneficiary | Consumers or beneficiaries who, for commercial, loyalty, or other reasons, benefit from products or practices carried out by the seed. | Niche |
| Supplier | Suppliers of raw materials through a commercial, in-kind, or barter agreement with the seed. From a circular economy lens, suppliers are of utmost importance for seeds. | Niche |
| Professional advisor | Individuals or groups with professional expertise to advise the seed on a paid or volunteer basis. | Niche; regime |
| Financial institution | Business entities (e.g., banks, credit unions, pension trusts) that mediate financial monetary transactions by the seed. | Regime |
| Civil society organization | Non-state, not-for-profit, voluntary entities formed by people in the social sphere that are separate from the state and the market (e.g., community-based organizations, non-governmental organizations). | Niche; regime |
| Grassroots movement | Self-organized individuals who seek to bring about changes in social policy or influence an outcome at a local level. | Niche |
| Educational or research centers | Primary and secondary schools, technical schools, universities | Regime |
| National donors | Country-based donors who provide non-refundable aid on a competitive basis or by allotment. | Regime |
| International donors | Regional or global donors that provide non-refundable aid on a competitive basis or by allotment. | Regime; landscape |
| Local government | Lowest tiers of government or public administration within a country (e.g., counties, districts, cities, townships, towns, municipalities, municipal corporations, shires, villages, or local government areas). | Regime |
| National government | The central government of a country, including national ministries, directorates, government secretariat, or any other agency that operates under the umbrella of the highest tier of government. | Regime |
| Private sector | Individuals, private companies, or organizations that group private companies/enterprises. | Regime |

model interdependencies and relationships that are meaningful for coalescence processes (Wang et al. 2013, Lazega and Snijders 2015).

In this context, we propose that conceptualizing the seeds' substrate as a multi-level network (Fig. 2) can provide a basis for analyzing and modeling the seeds' substrate to better understand the interdependencies between and amongst seeds and supporting actors (see Fig. 2 for an illustrative example). Specifically, a network-based approach can help develop and test hypotheses regarding the mechanisms that influence the emergence of the seeds' substrate and/or how specific network structures are associated with diverse outcomes (Bodin et al. 2019). Lastly, but beyond the scope of our analysis below, a social network approach can also help to hypothesize, based on previous literature and findings (e.g., Bodin and Crona 2009, Barnes et al. 2017), that certain network configurations provide opportunities for seeds to shape similar perceptions about systemic challenges, align on possible pathways, build trust, and drive innovation, thereby enhancing the latent transformative capacity of the network (Fig. 2). Although such hypotheses still await formal, empirical testing across case studies, the seeds' substrate concept applied through a multi-level network model facilitates articulating such hypotheses.

## THE SEEDS' SUBSTRATE CONCEPT IN PRACTICE: A CASE STUDY IN A SMALL-SCALE FISHERIES FOOD SYSTEM

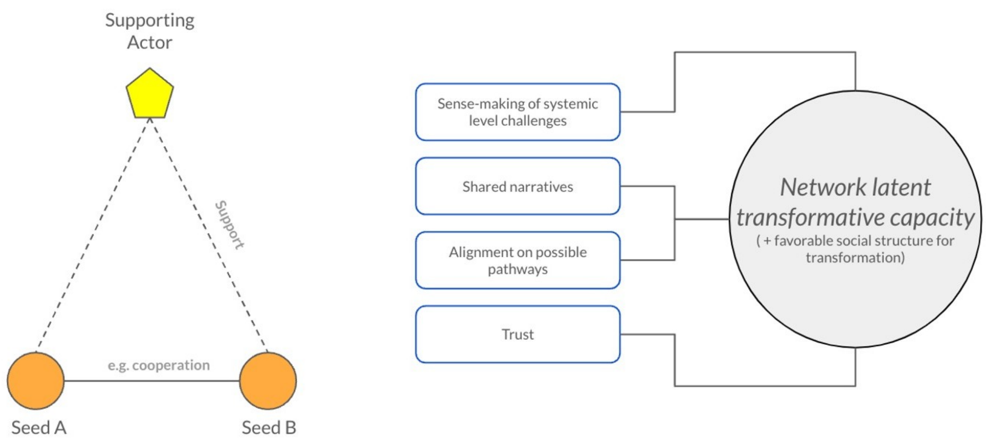
This section aims to simultaneously illustrate the seeds' substrate concept, discuss the empirical results specific to our case study, and offer some first-hand experiences and lessons learned from deliberately enacting a coalescing process through a transdisciplinary project. Our case study is the Fishing Transformations project (*Pescando Transformaciones*, https://goodanthropocenes.net/view-project/?project_id=6), an ongoing, deliberate seeds' coalescing process in the small-scale fisheries food system in Uruguay, a country of 176,215 km² and 3,444,263 people. Running since 2020, this transdisciplinary process, in which researchers acted as conveners of a carefully designed transformative space (*sensu* Pereira et al. 2020), aims to elevate small-scale fisheries seeds beyond the niche level, providing opportunities and time for seeds to coalesce (Juri et al. 2023) and empowering them to take both individual and collective actions (Gianelli et al. 2021, 2024).

Central to this effort is the need to address dominant narratives, which marginalize small-scale fisheries in Uruguay. Positioned within a political and economic context that prioritizes export-driven large-scale fisheries, small-scale fisheries often compete for the same species while being technologically and structurally outmatched by industrial fleets. They are also frequently reliant on precarious, informal value chains tied to industrial operations. Compounding these challenges, fish consumption in Uruguay remains low because of factors such as limited knowledge and culinary skills, taste preferences, relatively high prices, and low availability, particularly in inland areas. These dynamics reinforce a societal perception of small-scale fisheries as marginal and insignificant, generally overlooking their potential to thrive and deliver substantial local benefits if adequately supported and recognized.

The project engages collective experiences or initiatives (seeds) that promote new ways of thinking, doing, and being with demonstrated agency and interest in shaping change toward a sustainable small-scale fisheries food system. Seeds are led by small-scale fishers, gastronomes, small-scale entrepreneurs, and researchers, encompassing diverse initiatives that empower local stakeholders through innovation and collaboration, strengthen community networks, promote sustainable fishing practices, preserve cultural heritage, enhance product quality, and convert seafood waste into compost (see Appendix for a description of each seed).

Before starting with collective activities, the pre-existing common social fabric among seeds was mapped through interviews with seeds' leaders. Because of the lack of a social foundation that embraced all seeds, convenors took several steps to contribute to the creation of a socially cohesive community to ensure a social fabric capable of supporting the coalescing process (see details in Gianelli et al. 2021, 2022, 2024). This was followed by a collective effort to envision desirable futures through an arts-based method,

**Fig. 2.** An example of a working hypothesis that can be empirically tested with the multi-level network framework proposed within the seeds' substrate concept. The mechanism suggests that when two seeds (orange circles) are supported by the same supporting actor (yellow pentagon), the seeds themselves are more likely to cooperate (e.g., because of increased chances of meeting in common venues or through targeted actions by the supporting actor to induce cooperation between seeds). We hypothesize that this configuration can help in shaping collective sense-making, shared narratives, alignment in pathways, and building trust. Taken together, these elements would add to the network's latent transformative capacity and provide a favorable social structure conducive to a coalescence process.




resulting in a co-created meta-vision in the form of an artistic boundary object (Gianelli et al. 2024). The involvement of seeds in various activities (e.g., visioning, co-creation, dialogues) laid the foundation for a transformative space that has been active ever since. For methodological details on data collection and analysis in the case study, see the Appendix.

This case study's opportunity to quantitatively and qualitatively analyze the structural and relational characteristics of the seeds' substrate concept was due to: (1) the relatively small number of seeds and actors, which ensures that most relevant entities and relationships are mapped, while still being a case study at the national level, and (2) the level of detail of quantitative and qualitative data collected from very early in the process, including, for example, a comprehensive baseline before the transdisciplinary project started.

Before initiating the transdisciplinary project, the co-occurring seeds were already cooperating (10 ties with cooperative characteristics) and exchanging resources or information (seven ties with exchanging characteristics; Fig. 3A). Cooperation between seeds included organizing joint events (e.g., festivals, workshops) and co-developing projects, whereas examples of resource and information exchange included providing materials (e.g., sourcing festivals with fish), and sharing advice on new fishing practices or cooking skills. In addition, some of the more long-established seeds (Seeds 1 and 11) inspired or influenced the emergence of new seeds in similar or different contexts (Seeds 8, 3, and 7) by spreading or transferring principles and values (Fig. 3A and 3B). Overall, only 19% of the possible positive relationships between seeds occurred (network density = 0.19), with a link reciprocity score of 0.66: i.e., most positive relationships between seeds were considered reciprocal. On the other hand, competition and conflict also preceded researcher-led efforts to foster a coalition of seeds (Fig. 3A and 3B). For example, Seed 1 saw itself as providing knowledge and guidance to Seed 8, but Seed 8 saw Seed 1 as a niche competitor (Fig. 3A). On the other hand, there was an ongoing and reciprocal conflict between seeds, but no further details were given by any of the seeds.

**Box 1**: Network-related terms

Degree: The number of edges connected to an actor. In directed networks, out-degree is the total number of edges emanating from that node, whereas in-degree is the number of incoming edges.

Betweenness: a form of centrality that focuses on the place of an actor within a network structure. This is calculated by looking at how many times an actor sits on the shortest path (called the "geodesic") linking two other actors.

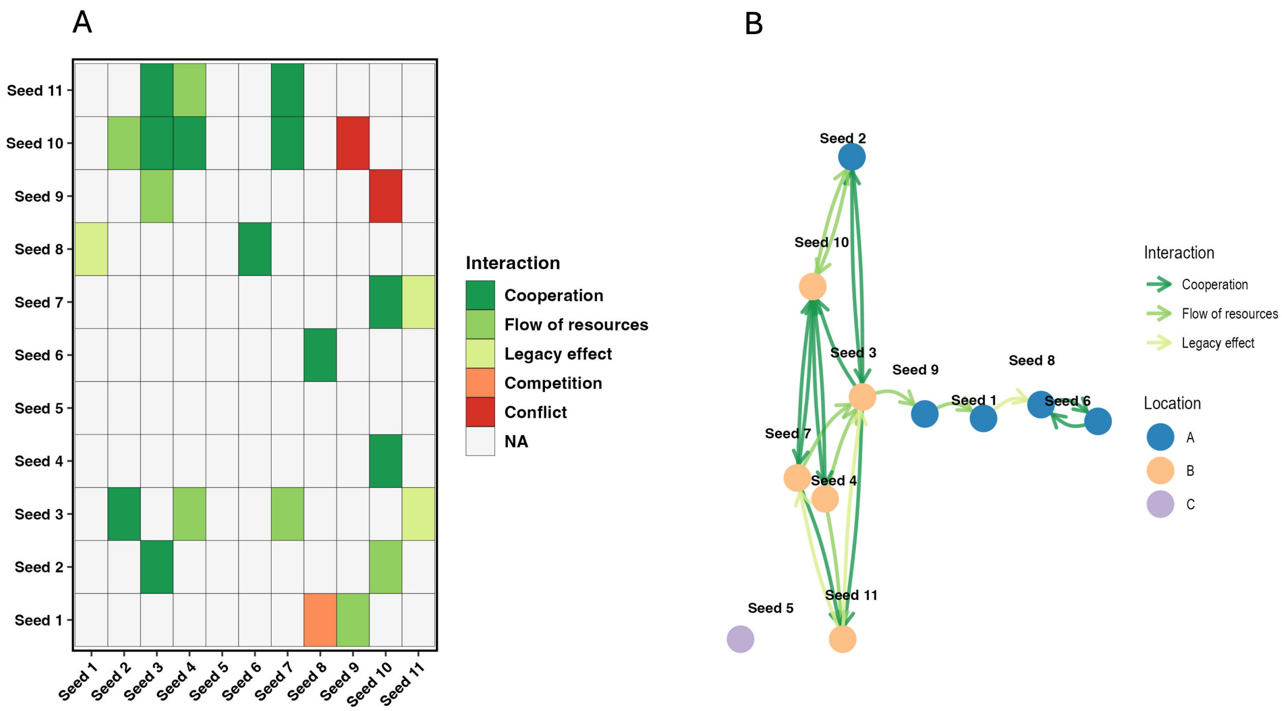
Network density: The number of existing ties divided by the number of possible ties.

Motifs: Patterns of interconnections, or subgraphs, that appear in an observed network.

Multi-level network: A network with more than one node type (e.g., seeds and supporting actors) with links across and within different node types.

Exponential Random Graph Models: A statistical model for social networks that enables to model multi-level (and other) network structures treating the network structures as endogenous (Wang et al. 2013). These models allow us to infer whether, in our observed network, there are significantly more (or fewer) network substructures of interest (e.g., reciprocated ties, or triangles) than we would expect by chance (Robins et al. 2007).

**Fig. 3.** (A) Pre-existing relationships between co-occurring seeds before initiating a deliberate effort to foster a seed's coalescing process. (B) Network of positive relationships (i.e., cooperation, flow of resources, legacy effect). The color of the arrows indicates the type of positive interaction, whereas the color of the nodes indicates the seed's site (A, B, and C).



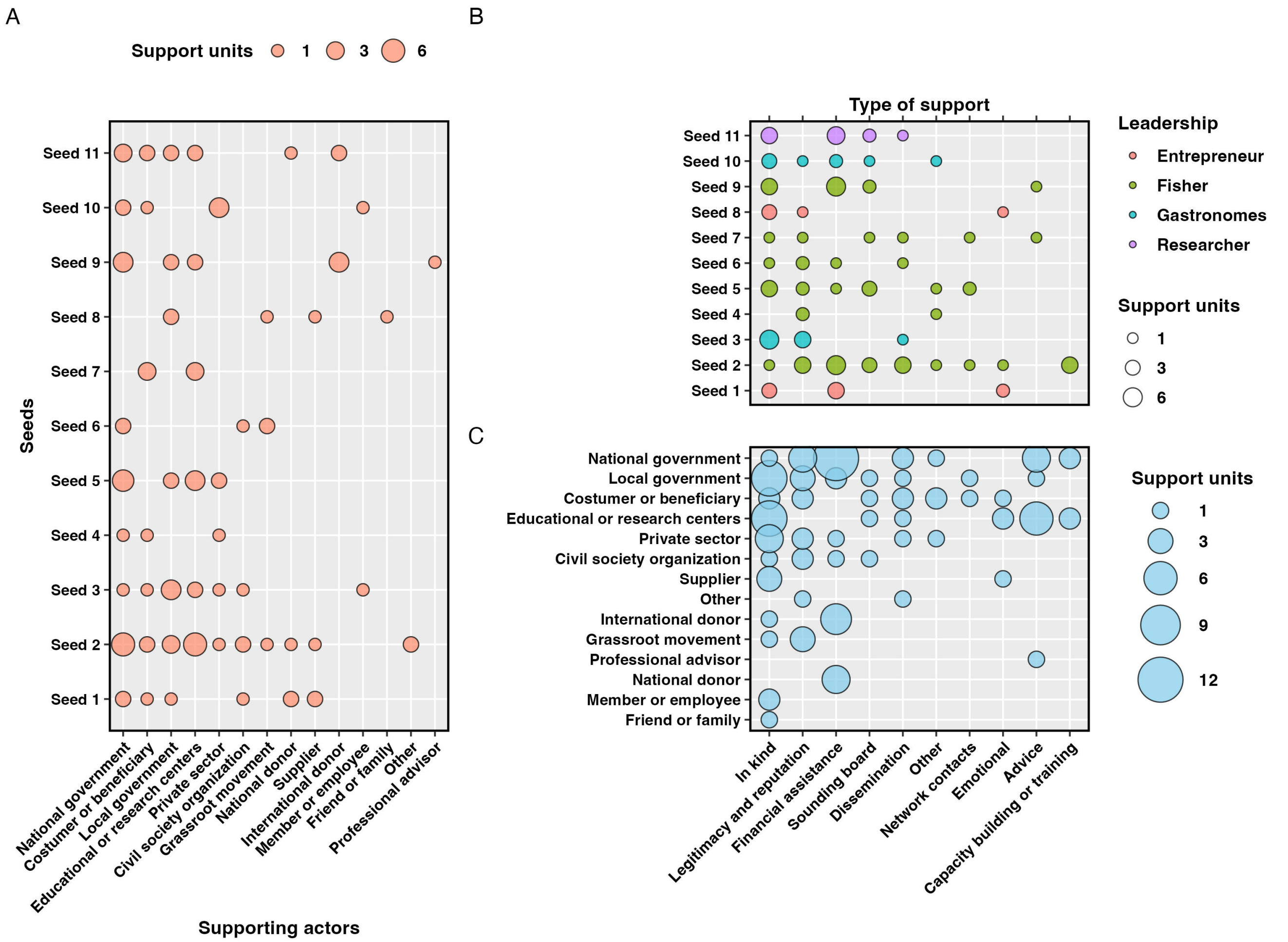

Although seeds' relationships can be either positive or negative, as explained above and shown in Fig. 3A, for the social network analyses we modeled seed connectivity by considering only positive interactions (i.e., cooperation, resource flow, coordination, legacy effect). In this context, the connectivity between seeds was strongly mediated by the site (Fig. 3B), with seeds from Site B highly connected, seeds from Site A loosely connected, and seeds from Site C completely disconnected from the rest of the seeds (in-degree and out-degree = 0, betweenness = 0). Whereas the two gastronomy-led seeds from Site B (Seed 3 and 10) had the highest degree (Seed 3: in-degree = 0.4 and out-degree = 0.4; Seed 10: in-degree = 0.3 and out-degree = 0.4), Seed 3 had the highest betweenness (0.27), indicating a key bridging role in the network (Fig. 2B). In Site A, a fisher-led seed strongly influenced by gastronomy (Seed 9), had a relatively high betweenness (0.20), but the lowest in-degree and out-degree (0.1 in both cases), meaning that despite not being highly connected it had the capacity to connect or bridge between otherwise unconnected seeds. For further explanation on network-related terms see Box 1.

The analysis of support revealed that prior to seeds' engagement in the project, there were: (1) up to 110 instances where seeds received support from other actors, and (2) multiple types of support were already in place (Fig. 4A), with in-kind (n = 30), financial (n = 25), legitimacy and reputation (n = 17), and advice support (n = 12) being particularly frequent (Fig. 4B). The types of support provided showed that most efforts were aimed at providing direct resources, either tangible or intangible. Yet, relatively little effort was made to improve seeds' training or capacity building (n = 4) or to expand their contact network (n = 2; Fig. 4C). When broken down by type of leader, fisher-led seeds accounted for almost 60% of support units. The remaining 40% of support was shared between gastronome-, entrepreneur-, and researcher-led seeds (Fig. 4B).

Fifty-four actors were identified and classified into 14 categories of supporting actors. The most common categories were national government (13 actors), education or research centers (10 actors), and local governments[1] (10 actors). In the context of the case study, the national government has multiple responsibilities and roles, whereas the competencies (and resources) of local governments are more limited. This hierarchical and centralized government structure explains why the majority of the support units were concentrated in the national government (about 24%), mostly in the form of financial assistance and legitimizing seeds' actions and goal, whereas local governments accounted for only about 14% of the support units, mostly through in-kind support.

Education and research centers accounted for 17% of the support units, providing advice and in-kind support to articulate seeds' needs with potential solutions. The least important supporting actors in terms of supporting units were professional advisors, friends or family, and seeds' members or employees (Fig. 4A). The median support received by seeds was 9 ± 6.1 support units (median ± standard deviation) with some seeds receiving considerably more (Seed 2: 25 support units) and others receiving considerably less (Seed 4: 4 support units). Nevertheless, receiving

**Fig. 4.** (A) Support units provided to seeds by each type of supporting actor. (B) The type of support received by each seed expressed as support units. (C) The type of support provided by each supporting actor expressed as support units.




more or less support than the median does not necessarily mean a seed is over- or under-supported because the seeds differ in their scope, needs, among others.

The modeling of the seeds' substrate through a multi-level network approach (using ERGM; see Appendix) showed that there was a positive tendency for seeds that are in the same site to be connected with each other ("site_MatchA"; Table 4). On the other hand, there was a tendency for centralization around supporting actors (Fig. A1), meaning that some supporting actors tend to be linked to many seeds. The latter was shown by the positive tendency of a supporting actor to have more links with seeds after already having more than one link ("XStar3B"). However, the tendency of a supporting actor to have more links with seeds after already having one link was negative ("XStar2B"), indicating that central supporting actors tend to have many links (Table 4 and Fig. A1).

Seeds themselves are not necessarily more likely to be connected (or vice versa) if they are supported by the same supporting actor: the "ATXAX" configuration was positive, but not statistically significant (Table 4). However, if the "site_X2StarAMatch" motif is not included in the model, then "ATXAX" is positive and significant. In other words, there may be an underlying tendency for seeds to be connected when they are supported by the same actor, but this could be mediated (at least partially) by the positive tendency for seeds to establish a relationship when they are in the same site. Note that the "site_X2StarAMatch" motif is also positive but not significant (Table 4). These results are likely influenced by the fact that the connectivity between seeds in this case seems to be mostly driven by belonging to the same site. If we assume that having a link between seeds does not influence the site of the seeds, then we can imply that being on the same site seems to influence the establishment of links between seeds. Despite the specific findings and some simplifications when designing these models (e.g., partially articulated network structure that omits links between supporting actors; Sayles et al. 2019), this multi-level network framework proved useful to analyze and further understand the underlying network mechanisms of the seeds' substrate.

**Table 4.** Results of the exponential random graph models (ERGM), testing specific network patterns in the seeds' substrate representing interdependencies between and amongst seeds and supporting actors. These network patterns are captured as network configurations or motifs (see Fig. 2). * Indicates significant results, and the sign of the parameter indicates the positive or negative effect of a specific network configuration. Stderr, standard error; SACF, sample autocorrelation function.

| Motif | Description | Parameter | Stderr | t-ratio | SACF |
|---|---|---|---|---|---|
| EdgeA | Links (baseline): tendency of seeds to be linked to each other | −2.02 | 2.22 | −0.03 | 0.24 |
| 2StarA | Centrality of seeds: tendency of a seed to increase their links to other seeds based on existing link(s) | 0.09 | 0.75 | −0.02 | 0.34 |
| 3StarA | Centrality of seeds: tendency of a seed to increase their links to other seeds after already having two links | −0.02 | 0.37 | 0.01 | 0.38 |
| TriangleA | Seeds clique (transitivity): tendency of two seeds to have a link with each other if they are also linked to the same seed | 0.16 | 0.98 | −0.03 | 0.28 |
| site_MatchA | Effect of site (homophily): tendency of seeds from the same site to be linked to each other | **1.94*** | 0.92 | −0.05 | 0.095 |
| XEdge | Activity of supporting actors (baseline): tendency of having links with seeds (i.e., providing support) | **−1.74*** | 0.63 | −0.01 | 0.08 |
| XStar2A | Centrality of seeds: tendency of a seed to increase their supporting actors based on existing links with supporting actors | 0.15 | 0.10 | −0.01 | 0.07 |
| XStar3A | Centrality of seeds: tendency of a seed to increase their supporting actors if already receiving support from two supporting actors | −0.01 | 0.01 | −0.02 | 0.05 |
| XStar2B | Centrality of supporting actors: tendency of a supporting actor to support more seeds based on existing support links | **−1.12*** | 0.34 | −0.06 | 0.66 |
| XStar3B | Centrality of supporting actors: tendency of a supporting actor to support more seeds if already supporting two seeds | **0.31*** | 0.09 | −0.08 | 0.91 |
| site_X2StarAMatch | Support homophily: Tendency of supporting actors to support seeds from the same site | 0.34 | 0.26 | −0.08 | 0.36 |
| Star2AX | Seeds-support interactions: Tendency of seeds that receive support from many actors to also have many links with other seeds | −0.12 | 0.14 | 0.005 | 0.22 |
| L3XAX | Links between supported seeds: Tendency of seeds that receive support from different actors to be linked to each other | 0.002 | 0.02 | 0.008 | 0.18 |
| ATXAX | Multi-level closure: Tendency of seeds sharing a supporting actor to form a link between each other (or vice versa) | 1.33 | 0.69 | −0.04 | 0.44 |

**Making sense of the case study**

The description and analysis of the seeds' substrate allowed us to identify the constellations of actors and interactions that preceded researcher-led efforts to deliberately foster a seed coalition. It also provided valuable lessons for better understanding the unfolding of the coalescence process since the inception of the transdisciplinary project. For example, whereas most of the seeds voluntarily decided to engage in collective activities, one seed refrained from active participation (Seed 9). This seed remained on the periphery, i.e., it accompanied the project in specific actions but was more interested in pursuing its agenda than in co-creating a collective agenda. Interestingly, this seed had a key mediating role in connecting other seeds and one of the sites (Site A) to the broader network before the project began. The characterization of the seeds and the analysis of their interactions allowed us to anticipate that Seed 9 was mostly interested in "amplifying within" (*sensu* Lam et al. 2020), and also had an ongoing conflict with another seed. Exploring the seeds' substrate before any attempt at coalescing proved to be instrumental in ensuring that everyone had a place and role in the project in which they felt comfortable, and in actively developing strategies for engaging other seeds who would otherwise be disconnected from the network. On the other hand, the simultaneous participation of two competing seeds eventually led to direct conflict, which unfortunately ended with one of the seeds withdrawing from the project. Finally, less connected seeds seemed to be more prone to engage in collective activities than the well-connected and supported seeds. Although we cannot rule out the possibility of mere coincidence, this observation deserves further attention, as spaces facilitated during coalescence processes may simultaneously act as an opportunity for isolated seeds or as places where time and effort are diverted from more consolidated seeds with a clear own agenda. However, we recognize that social interactions are complex and may not be able to be fully explained, let alone modeled. Reduced interest, limited time, or simple aversion are examples of factors that may hinder coalescing efforts but are difficult to empirically capture and describe. Finally, we argue that the seeds' substrate holds latent potential, meaning that although opportunities and capacities for coalescence can be present and available, they are not necessarily harnessed by everyone at once.

The network analysis suggested that there are central supporting actors, which implies that they could have a high capacity to influence several seeds simultaneously (Fig. A1). This finding was reinforced by the descriptive analysis of support, which showed that both national and local governments and educational and research centers were key supporting actors, providing multiple and diverse support. Although the national government is a key supporting actor, it can also be a gatekeeper of systemic change, whose active involvement in transforming the small-scale fisheries food system has been limited (Gianelli et al. 2024). Therefore, although it is important to support positive emerging changes, it is equally important for key supporting actors to simultaneously dismantle practices, structures, and values that perpetuate the prevailing system.

Given the key role of seeds' site in this case study, the role of territorialization in configuring seeds' relationships must be partially undermined if the overall goal of fostering a process of national coalescence is to be achieved. To this end, collective and participatory actions (e.g., cross-site visits of seeds and virtual meetings) have been organized in the context of the transdisciplinary project. A potential approach to empirically test the impact of such actions in reducing the effect of the seeds' site is, first, to identify novel interactions among seeds and between seeds and supporting actors as coalescing efforts unfold over time and, second, to use the same network modeling approach to analyze changes in the effect of seeds' sites through a longitudinal analysis (e.g., Bodin et al. 2019, Barnes et al. 2020).

## DISCUSSION

Our paper introduced the concept of the seeds' substrate and offered a novel method for characterizing it based on the interactions among co-occurring seeds and between seeds and supporting actors. Using the existing literature and the empirical results of a case study, we derived several categories and definitions for seeds' interactions, types of support, and supporting actors that collectively constitute the seeds' substrate concept. Specifically, we identified seven types of interactions between seeds, nine types of support, and 14 different supporting actor categories. Furthermore, we presented a multi-level network approach, applied on the basis of an ERGM framework, for analyzing the seeds' substrate and testing specific hypotheses within this modeling approach. In doing so, we contributed to filling a gap in the SOGA project literature and unpacked a key, but largely unexplored, subprocess of the SOGA's theory of change: moving from periods of experimentation to periods of coalescing.

### Connectedness and support as key factors for coalescing

The SOGA project recognizes the potential of informal networks of individuals operating both inside and outside the dominant system in bringing about transformative change (Bennett et al. 2016). These networks promote information sharing, expertise, and social learning, and explore alternatives to the dominant system when opportunities arise (Wutich et al. 2020). Although the importance of networks has been recognized, their role in supporting the emergence and growth of seeds has not been extensively studied or, at best, approached abstractly (see Tuckey et al. 2023, Vrettos et al. 2024). This paper provided a lens and empirical method for advancing knowledge about multiple types of relationships (e.g., cooperation, conflict) and structures within and across levels, which in turn allows for the development of empirically grounded hypotheses focused on coalescing processes (Bodin et al. 2020). It also provided a vivid example of an ongoing process facilitated by researchers, in which a network of seeds began a coalition toward desirable, place-based futures.

The unfolding of the SOGA project partly explains why connectedness and support have remained relatively unexplored insofar. The project began as a concerted effort to identify seeds at the global level (Bennett et al. 2016), and later moved to the development of desirable or radical visions based on subsets of seeds grouped by theme and/or region (Falardeau et al. 2019, Sellberg et al. 2020, Hamann et al. 2020, Raudsepp-Hearne et al. 2020), and more recently it has begun to address seeds in specific contexts (Bachi et al. 2023) or through particular projects (Buendía et al. 2023, Gianelli et al. 2024, and several papers in this Special Feature). It is at this later stage that the analysis of seed connectedness and support, the seeds' substrate concept, has the greatest potential and implications.

Conversely, a large body of social-ecological research literature has emphasized the role of connectedness and support for resilience (e.g., Biggs et al. 2012, Bodin 2017), including the importance of social network configurations that precede social-ecological transformations. For instance, Olsson et al. (2006) and Herrfahrdt-Pähle et al. (2020) documented the role of self-organized networks in providing novel ideas and practices for transformations. Moore et al. (2014) highlighted the role of linking ties across multiple scales in the early stages of sustainability transformations. Similarly, Barnes et al. (2017) suggested that network structures that facilitate cross-scale collaboration are a prerequisite for transformations while cautioning that favorable social structures do not guarantee successful outcomes. Importantly, both connectedness and the timing and type of support are phase-dependent (Klyver et al. 2018). For example, although linking ties may be important for enacting change, bonding and bridging ties are considered critical for navigating change (Gelcich et al. 2010). Although not analyzed in this contribution, the interaction between type of support and timing can be accommodated within the seeds' substrate and empirically analyzed through longitudinal analyses (e.g., longitudinal network analysis using multilevel network modeling tools; e.g., Bodin et al. 2019, Barnes et al. 2020). This analytical framework can help disentangle the relational characteristics that shape seeds' substrates over time, which can influence system-level outcomes (Bodin et al. 2019).

Through connections to and support from meso-scale actors, seeds can gradually and slowly influence the macro-level narrative (Sellberg et al. 2022). These actors, whose power is context-specific (e.g., in some contexts, local governments are quite powerful actors, whereas in others national governments are dominant), are key to elevating change to the meso-scale, supporting individual seeds or coalitions of seeds, and thus increasing their disruptive impact (Sellberg et al. 2020). Regarding food systems, supporters that help build relational values between consumers, producers, and the environment are particularly relevant for food-related seeds (Pereira et al. 2019, Sellberg et al. 2022). In our case study, chefs, restaurants, and cooking schools were central to connecting and supporting seeds in the small-scale fisheries food system (Gianelli et al. 2024). In other contexts, actors such as supermarkets, wholesalers, local food nodes, regional hubs, civil society initiatives, and schools may also play key roles (Pereira et al. 2022). Additionally, Vrettos et al. (2024) emphasize the role of communities in supporting seeds and warn against the potential cooptation by regime actors, arguing that powerful actors may not support seeds if these pursue disruptive pathways that involve confrontation with the prevailing regime (Rutting et al. 2023).

### Further improving the seeds' substrate concept

The seeds engaged in our case study imagined and enacted novel strategies for context- and place-specific food system transformation (Gianelli et al. 2022, 2024). Their mutual reinforcement represents a promising entry point for initiating change in a system characterized by inertia and resistance but in need of transformation (Gianelli et al. 2024). Nevertheless, we acknowledge that the seed sample on which our results are based is relatively small and mostly characterized by symbiotic pathways (i.e., seeds cooperating with the state and/or the market, as defined by Wright 2020). Thus, we call for further research on the seeds' substrate through: (1) case studies with larger sample sizes; (2) cross-case studies comparing the seeds' substrate across different thematic seeds (e.g., food systems, energy transitions, circular economy, urban design and planning, sustainable finance, degrowth) and transformative pathways (e.g., pathways aligned with markets or the state, pathways at the fringe of the regime, pathways aimed to confront and disrupt the regime); and (3) longitudinal case studies to empirically analyze changes in the seeds' substrate as coalescing periods unfold.

So far, we have emphasized positive relationships in coalescing processes, overlooking the role of conflict. Conflict can be a catalyst for social learning and transformation if tensions are surfaced and explored constructively (Chambers et al. 2022). Within the seeds' substrate concept, conflict needs to be better articulated: for example, by reconciling positive and negative ties between co-occurring seeds (Bodin et al. 2020). In addition, coalescing processes involve negotiation and realignment, so seeds are likely to engage in cooperation and conflict either simultaneously or in tandem. Again, social network approaches can accommodate both cooperative and conflictual ties to the seeds' substrate, enhancing our understanding of the consequences of each for coalescing processes (Bodin et al. 2020). A critical aspect that needs further attention is the power relations between seeds and supporting actors. Almost inevitably, the provision of support involves the creation of some kind of power dynamic that may have unintended visible or invisible consequences, such as dependency, domination, or coaction. Therefore, unpacking the power dynamics within the seeds' substrate represents a future research topic to better understand how "power to," "power over," and "power with" (Avelino et al. 2023) can either hinder or facilitate seeds' scaling or coalition formation.

### Recommendations for applying the seeds' substrate

Based on our experience in trying to actively and deliberately move from periods of experimentation toward periods of coalescence, we suggest considering the following actions: (1) decide on the geographical (e.g., country, region, site) and thematic boundaries (e.g., food system) and/or goals around which seeds can coalesce; (2) identify and map individual co-occurring seeds in a given region and time; (3) characterize seeds' features (e.g., goals, strategies) based on interviews and/or secondary sources; (4) identify and systematize positive and negative existing relationships among seeds to anticipate synergies and/or potential conflicts; (5) identify and systematize types of support and supporting actors; (6) use qualitative analyses to explore the seeds' substrate, aiming to understand and ultimately interpret existing relationships and/or emerging network-level patterns (see next item); (7) if data and modeling expertise are available, model the seeds' substrate (either partially or entirely) using network approaches to explore the patterns of interdependencies between diverse seeds and supporting actors and how these network structures could influence coalescing processes and their transformative potential; and (8) create enabling conditions and facilitate "safe enough" spaces when seeds can interact on equal ground, and perhaps coalesce. Finally, rather than avoiding tension and conflict, coalescing facilitators (e.g., researchers) can use conflictive situations to demonstrate the value of creating spaces where people value the opportunity to challenge each other's diverse perspectives (Chambers et al. 2020). These recommendations are intended as a guide for future efforts but are by no means prescriptive.

Coalescing processes can take many forms and can be motivated by diverse intrinsic (e.g., values, mindsets) and extrinsic factors (e.g., incentives, disruptions) well beyond the case study we used as an illustrative example. Whereas this contribution emphasizes deliberate coalescing efforts, pressures from the macro-level often influence why and how seeds coalesce. Disruptive drivers or shocks can create windows of opportunity for seeds to address social needs and expand their activities through cooperation, adaptation, and innovation, thereby gaining social recognition and momentum (Nemes et al. 2021). For example, Nemes et al. (2021) and Love et al. (2021) highlighted how COVID-19, a global-scale disruption, enabled niche-level initiatives to expand their reach, diversify their activities, and engage new participants in sustainable practices related to local food systems. This example underscores the importance of contextual factors beyond the seeds' substrate in triggering or enabling alternative proto-regimes, whether they are ephemeral or enduring.

Finally, a social network approach focuses on the relationships and networks underlying the seeds' substrate, but it does not reveal how mobilized seeds collectively articulate and create narratives that open up possibilities for change (Ernstson 2011). Such questions that are important for understanding seeds' coalescing processes but that go beyond the analysis of the structural characteristics of networks may need to be investigated through additional analytical approaches.

## CONCLUSIONS

In this article we offered a theoretically informed and empirically derived method for characterizing and modeling the seeds' substrate. We hope that by better understanding the structural and relational context where seeds emerge, operate, and thrive, deliberate coalescence processes will have a better chance of initiating broader change toward Good Anthropocenes. This study addressed a gap in the SOGA project by examining the transition from periods of experimentation to periods of coalescing, a transitional process that is often overlooked. In doing so, we have identified and defined several components and elements, and highlighted the role of key supporting actors and the underlying relationships among seeds and between seeds and supporting actors. We hope that these elements will pave the way for future research to further unpack the seeds' substrate concept. Though a significant step forward, the seeds' substrate concept will benefit from better accounting for power dynamics between seeds and supporting actors, as well as reconciling positive and negative relationships between co-occurring seeds.

The case study allowed us to illustrate the application of the seeds' substrate concept, providing empirical examples of the potential constellation of relationships between co-occurring seeds, the support seeds receive, and the supporting actors at the niche, regime, and landscape levels. We also presented some advantages and limitations of using a social network approach to model a real-world example of a seeds' substrate, as well as its use as a baseline against which to compare the unfolding of a coalescence process. More broadly, this paper provides valuable elements for informing multi-level, multi-phase sustainability transformations, particularly in the process of deliberately fostering the coalition of seeds to form proto-regimes. To this end, we offered a set of recommendations for researchers interested in fostering seed coalescence processes by combining a data-driven approach with the creation of a socially cohesive community. We expect the seeds' substrate concept to be useful in a wide and diverse range of social-ecological contexts.

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[1] Although we have combined the second and third tiers of government under the local governments category, other authors might find it more useful to separate them into two or more categories, depending on the context.

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**Data Availability:**

*The data and code that support the findings of this study are available on request from the corresponding author, IG. Ethical approval for this research study was granted by the Bioethics Committee of the Universidade de Santiago de Compostela (Codes: USC-39/2021 and USC 23/2022).*

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# APPENDIX

## Mapping seeds and support

Seeds mapping was carried out following an emerging issue analysis (Hichert et al. 2021) and operationalized in three steps (see details in Gianelli et al. 2024): (1) consultation with the personal and professional networks of the co-authors; (2) general web searches using the search string ("pesca artesanal" AND "innovación" AND "Uruguay") and specific searches on the websites of national and local government organizations potentially related to small-scale fisheries or rural development and innovation; and (3) snowball sampling, interviewing individuals from the seeds identified in the previous steps. The selected seeds (Table A1) met either nomination criteria or documentation criteria, indicating their positive and innovative impact on the future of local small-scale fisheries. No other criteria (e.g. number of people engaged, years since inception, scope or scale of action) were used to circumscribe what a seed is in the context of our case study.

Table A1. Seeds identified for the case study in Uruguay (i.e. the *Fishing Transformations* project). Modified from Gianelli et al. (2022).

| **Seeds** | **Seeds description** |
|---|---|
| Armonía | An enterprise that uses environmentally friendly fishing gear and maximizes process efficiency and seafood quality. The initiative supplies local, fresh fish to restaurants in Punta del Este. |
| COOPESCONAND (Cooperativa Pesquera de Consumo Andresito) | A fishers' cooperative that promotes the consumption of freshwater fish and enhances the value of inland small-scale fisheries in Uruguay through technological advancements in post-harvest processes and organizational strengthening. |
| Escuelita de Pesca Artesanal | A family-based project that revitalizes small-scale fisheries by preserving Punta del Diablo's fishing heritage and adding value to local seafood. |
| Grupo POPA (Por la Pesca Artesanal de Piriápolis) | A participatory action-research group that creates a space for knowledge exchange among fishers, researchers, and other stakeholders to address local challenges in small-scale fisheries in Piriápolis. |

| | |
|---|---|
| Hermanos Kurta | A family-based enterprise focusing on coastal fish species, employing advanced techniques for product quality, processing, and storage. Based in Playa Verde, it supplies fresh, high-quality fish to restaurants in Montevideo. |
| Jardín Primitivo | An enterprise that transforms seafood waste from small-scale fisheries in Punta del Diablo into organic compost. |
| Pacto Oceánico del Este | A project that strengthens connections between small-scale fishers, chefs, and citizens, promotes awareness of local fishing practices, and educates children to inspire changes in fish consumption patterns in Maldonado. |
| Abono de Mar | An enterprise that transforms seafood waste from small-scale fisheries in La Paloma into organic compost. |
| Almejas Palmares | A family-based enterprise in Palmares de La Coronilla that harvests, processes, distributes and sells yellow clams to restaurants in various locations along the coastline. |
| Aquí se Pesca, Aquí se Cocina | A gastronomic festival that celebrates the culture of small-scale fisheries and promotes the consumption of local seafood in the coastal area of Uruguay. |
| Cocina de La Barra | An associative gastronomic enterprise led by fisherwomen, which adds value to local seafood from Rocha Lagoon while preserving its cultural identity. |

We combined semi-structured interviews with secondary source analysis to map seed relationships and support before starting with the transdisciplinary project. Interviews with key informants of each seed were conducted in person or remotely between August and October 2021. First, we asked about general topics such as the seed's history, structure, goals, strategies, amplification mechanisms, and future aspirations. Second, we asked explicitly about the support they received and the supporting actors that were key to the seed's emergence and persistence. Finally, we mapped pre-existing relationships between previously identified seeds by naming each seed to the interviewee and asking them to tell us more about the nature of the interaction or relationship (if any) with each seed. We recorded, transcribed, and analyzed interviews qualitatively using a combination of deductive and inductive codes. Complementary, we gathered additional information from secondary sources (e.g. press, websites, interviews on TV or radio), placing special emphasis on identifying supporting actors and types of support.

Relationships between seeds were determined following a three-step process. First, we classified interviewees' responses into a gradient of interaction strength (Gianelli et al. 2022): (1) no interaction (e.g. "*I am not aware of the seed*"); (2) nonpersonal, weak interaction (e.g. "*I have heard about the seed before*"); (3) personal, weak interaction (e.g. "*I know some of the members of the seed but I'm not fully aware of what they are doing*"); (4) cooperation (e.g. "*I cooperate or have cooperated with other seed*"); (5) co-membership (e.g. "*In addition to my own seed, I am also actively involved in another seed*"). Second, we categorized relationships into negative, neutral, and positive relationships. Finally, we deductively coded the underlying nature of the existing relationships following the categories in Table 1.

We triangulated information derived from the interviews and secondary sources to identify types of support and supporting actors. We used an inductive-deductive approach to develop categories for types of support iteratively and supporting actors (Tables 2 and 3), complementing or reinforcing our inductive analysis with other categories documented in the entrepreneurship literature (Suchman 1995, Hanlon and Saunders 2007, Klyver et al. 2018). From this specific literature, we also drew two concepts: support units (i.e. the number of different types of support provided by a supporting actor) and support index (i.e. the sum of different types of support divided by the maximum number of support types) (Hanlon and Saunders 2007).

**Modeling the seeds' substrate**

To construct the network of relationships between seeds (i.e. one-level network), we modeled seeds as nodes and relationships between seeds as directed links (e.g., Seed 1 cooperated with Seed 2, without assuming that Seed 2 cooperated with Seed 1). Note, however, that we restricted this network to positive relationships only, assuming that these relationships provide a favorable foundation for transformative processes (Barnes et al. 2017). The network between seeds was analyzed using aggregated network measures (e.g. network density and average degree) and node-specific metrics (e.g. degree and betweenness). Analysis and visualization of social networks were conducted in the "tidygraph" (Pedersen, 2020), "igraph" (Csardi & Nepusz, 2006), and "ggraph" (Pederesen, 2021) packages of the free software R (R version 4.2.2).

To construct the network between seeds and supporting actors (i.e. two-level network), we modeled both seeds and supporting actors as nodes at different levels and support relationships as links across levels. A supporting link was assumed when the type of support and the supporting actor were easily identifiable from data triangulation. Although links between supporting actors are possible or even likely, interviewing every supporting actor was beyond the scope of this research. To overcome this problem and unravel the components of the seeds' substrate, we used a partially articulated network structure that omits links between supporting actors (Sayles et al. 2019). To simplify our analysis, we aggregated all positive relationships between seeds and all supporting links regardless of their type. Thus, a supporting link implies the presence of support, regardless of the type of support provided.

Following Bennett et al. (2016) and Felici and Mazzocchi (2022), we included seed site as a key attribute in network modeling. In our case study, we conceptualized sites as the higher-tier administrative-territorial units in Uruguay (locally known as "Intendencias"). Thus, seeds were distributed across three sites as follows: Site A (Seed 1, 2, 6, 8, and 9), Site B (Seed 3, 4, 7, 10, and 11), and Site C (Seed 5).

To explore and illustrate one of the potential underlying factors that configure the seeds' substrate, we tested the following working hypothesis: if two seeds are supported by the same supporting actor, then the seeds themselves are more likely to be connected. To this end, we analyzed the two-level network using multi-level exponential random graph modeling (ERGM) in the MPnet software (Wang et al., 2009). This method models network connections based on different local network processes, which are represented as micro-level network configurations or 'motifs' (Wang et al., 2013). These models assume that network links self-organize and influence each other (ibid). In a multi-level network context, this means that links in one network can influence links in another connected network.

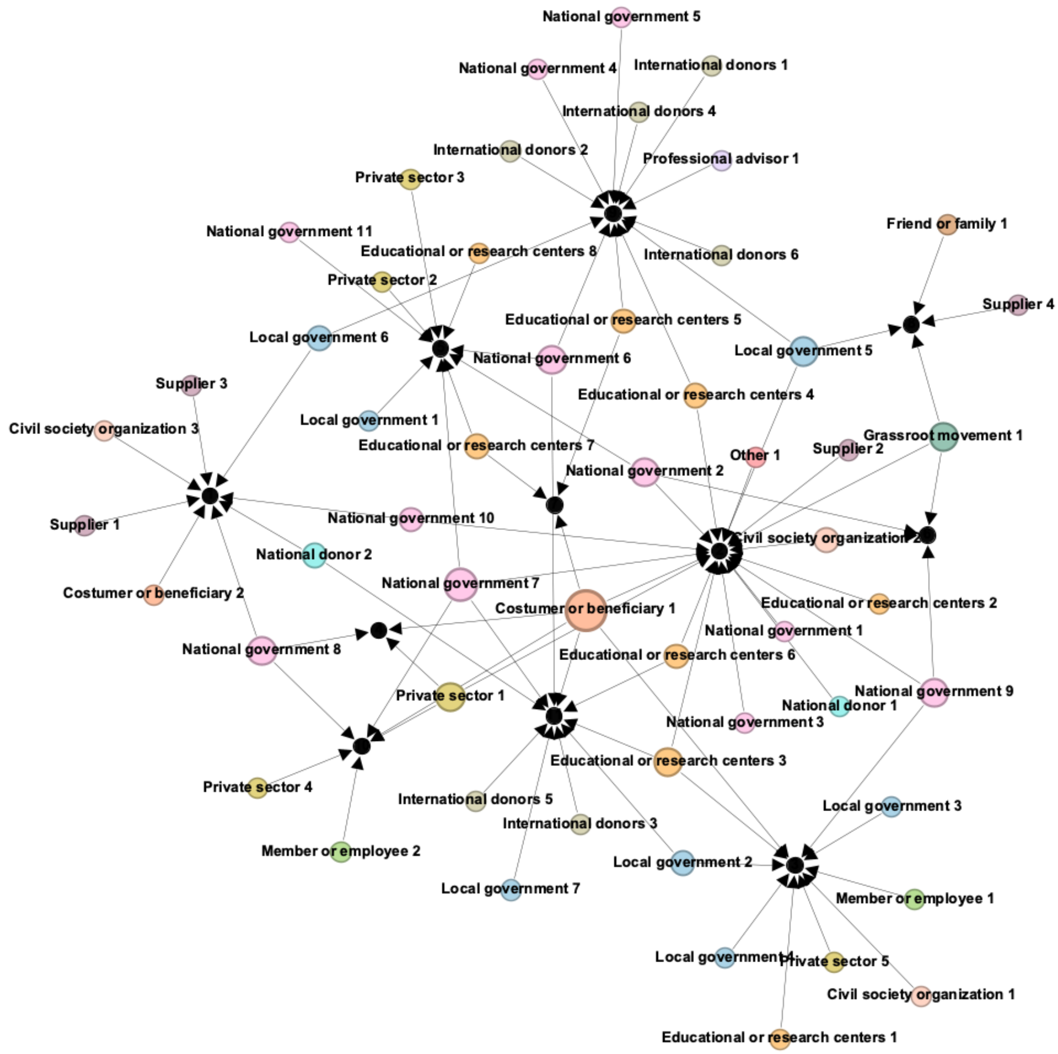


**Figure A1.** Multi-level network of seeds (black circles) and supporting actors (colored circles) showing out-degree centrality as the size of the nodes of supporting actors.

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