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RESEARCH ARTICLE

The Role of Polycentric Governance, Public-Private-Civil Partnerships, and Citizen Science as Developed by the C2IMPRESS Project in Building Disaster Resilient Societies*

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Abstract
The destructive impacts of natural hazards challenge communities. This study investigates how polycentric governance, public-private civil partnerships and citizen science can enforce socially resilient communities despite natural hazards. To understand the ways in which these participatory mechanisms can enforce social resilience, literature on the intricate concepts of social resilience and vulnerability and their confluence is conducted. Moreover, polycentric governance, public-private-civil partnerships and citizen science mechanisms and their benefits and disadvantages are considered. This study will demonstrate that the social resilience aspects of reactive capacity, leadership, community cohesion and efficacy, community networks, and system-level responses are found in all of the participatory mechanisms. Exploitation of economic, social, and cultural capital is reflected only in public-private-civil partnership models, and place attachment and mobility are revealed only in polycentric governance. Finally, polycentric governance and citizen science also entail characteristics of local environmental know-how. Although all three mechanisms contribute significantly to social resilience, the actual development of these participatory mechanisms on social resilience remains difficult to measure.

Keywords: social resilience • polycentric governance • public-private-civil partnerships • citizen science • natural hazards

* The paper is also part of an internship report submitted for the Master's Degree in Human Ecology at the New University of Lisbon (this reflection encompasses the dual purpose of contributing to the project and to the academic career at FCSH|UNL)

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Communities worldwide are grappling with the increasing vulnerability posed by natural hazards. The frequency and intensity of these disasters, intensified by climate change and environmental degradation, have highlighted the urgent need for effective solutions to enhance community resilience. Natural hazards, including hurricanes, floods, wildfires, and earthquakes, pose significant threats to lives, livelihoods, and infrastructure. As populations grow and urbanisation accelerates, more communities find themselves at risk, with vulnerable groups often bearing the brunt of these disasters. The challenges are multifaceted. Infrastructure deficiencies, inadequate emergency response and monitoring mechanisms, governance problems, and socioeconomic disparities amplify the impact of natural hazards, leaving communities reeling in the aftermath (Hossain, 2017). Addressing these challenges requires a comprehensive approach that goes beyond short-term fixes. Communities require solutions that strengthen physical infrastructure and foster community resilience. These objectives are in line with the C2IMPRESS project, which seeks to create more understanding and awareness about multi-hazard risks to enable disaster-resilient societies.[1]

The C2IMPRESS project argues that through mechanisms of polycentric governance this disaster resilient society can be organised. Polycentric governance supports communities in constructing governance systems that are specifically suited to the unique characteristics and challenges of their territories. This customisation acknowledges the diverse environmental, political, social, and cultural factors influencing disaster management.[1]

Polycentric governance is argued to be obtained through the public-private-civil partnerships (PPCP), which is a collaborative framework that brings together public sector, private sector, and civil society organisations to address social, economic, and environmental challenges. It recognises the complementary strengths of these stakeholders and emphasises collaboration, shared responsibilities, and mutual accountability. The objectives of PPCP include incorporating all actors within society into decision-making processes, proposing a new multi-party engagement structure, increasing transparency, improving collective intelligence and fostering the sharing of knowledge and experiences. PPCP uses innovative methods such as Design Thinking and Agile methods to promote collaborative problem-solving and stakeholder engagement. Living labs, a key component of PPCP, serve as platforms for inclusive interaction, collective intelligence, and innovation, bringing together diverse stakeholders to co-create solutions to complex problems. The project establishes multi-stakeholder working groups called “PPC-LL” (public-private-civil living lab) in each territory. These groups include representatives from the public, private, and civil society sectors and meet to bring about ideas for the establishment of a polycentric system of governance that goes beyond the State in natural disaster management projects. The proposed PPCP-LL enables the initiation of a process that fosters cohesion, dialog,

and trust among stakeholders who were not initially connected. Overall, PPCP, along with living labs and innovative methodologies, aims to establish polycentric management frameworks tailored to specific contexts, promoting inclusivity, collaboration and the co-creation of solutions for sustainable development and disaster risk management.[1]

Additionally, citizen science plays a pivotal role within the public-private-civil partnership framework, particularly in initiatives like the C2IMPRESS project. Citizen science involves engaging citizens as active participants in scientific research and problem-solving processes. In the context of PPCP, citizen science extends the inclusivity of data collection by involving individuals from diverse backgrounds and communities. Citizen science facilitates the systematic and inclusive engagement of citizens throughout the project. This involvement empowers individuals to contribute their knowledge, perspectives, and experiences to address social, economic, and environmental challenges, particularly those related to disaster management and climate change resilience. This paper analyses resilience and vulnerability and their interconnectedness and examines how polycentric governance, PPCP, and citizen science can enforce disaster-resilient societies.[1]

Resilience and Vulnerability

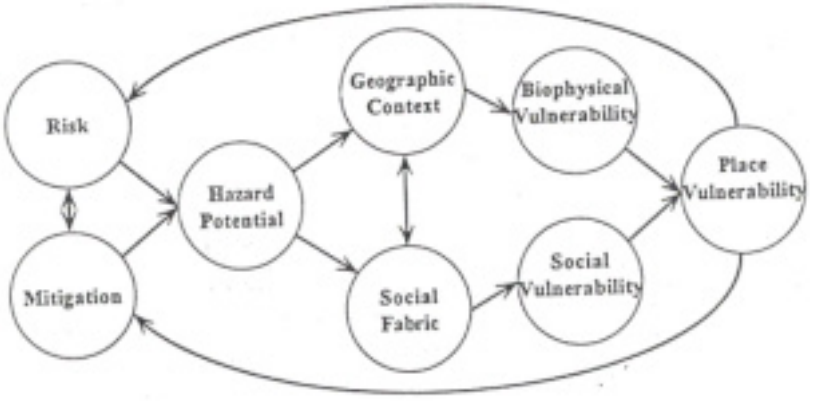
While resilience and vulnerability within social-ecological hazard contexts share common ground, they represent distinct dimensions that contribute to shaping a community's ability to withstand and recover from hazards. Therefore, it is important to be self-reflexive and critical of these concepts. Where resilience focuses on the study of transformation and learning and can highlight positive actions and their advancement, vulnerability concentrates on power and the restraint of agency and can illuminate political elements that hinder social-ecological change (Miller et. al., 2010). To avoid confusion, a clear understanding of the concepts is imperative.

Vulnerability. There is no general agreement on the definition of vulnerability, which could be attributed to its extensive use across disciplines (Cutter, 1996). In this paper, just as Cutter et. al. (2003), our explanation of vulnerability differentiates between biophysical and social vulnerability and focuses on the latter. In this manner, vulnerability goes beyond risk exposure and incorporates the social system, level of development, and infrastructure present in a certain area (Peduzzi et. al., 2009), thus acknowledging the socially constructed component of disaster vulnerability (Morrow,

1 C2IMPRESS – Co-creative Improved Understanding and Awareness of Multi-hazard Risks for Disaster-Resilient (HE 2021-2027 (Grant Agreement No 101074004). The author is a member of the research team and has completed a curricular internship hosted by the National Laboratory of Civil Engineering (Portugal). Link of the project: URL: Home | C2IMPRESS; The author is also undertaking a Master's Degree in Human Ecology at the New University of Lisbon (this reflection encompasses the dual purpose of contributing to the project and to her academic career at FCSH|UNL).

1999). The numbers of Peduzzi et. al. (2009) exemplified the necessity of the sociological lens of this definition. They show that the least developed countries accommodate 11% of the people who are vulnerable to disasters yet endure 53% of all disasters, which contrasts with the most developed countries that accommodate 15% of the people who are vulnerable to disasters yet only experience 1.8% of hazards (Peduzzi et. al., 2009).

Cutter (1996) synthesises three theoretical streams of vulnerability, various measurement techniques for vulnerability, causal linkages, and spatial outcomes of vulnerability into a hazard-of-place model. It establishes itself on locality as a fundamental unit of analysis and incorporates the elements of change for all actors. Her model works as follows: the overall hazard potential is founded on mitigation – which attempts to decrease the risk - and risk - which consists of the probability of a disaster and its consequential nature. Effective mitigation can lessen risks, whereas poor mitigation can augment risks. Hazard potential is filtered through two contexts: social and geographical. The social circumstances determine the social vulnerability of the area and consist of socioeconomic indicators, awareness of risk, and the capability to respond. Geographic location and proximity determine biophysical and technological vulnerability. The intersection of social and biophysical vulnerabilities shapes the vulnerability of place. This vulnerability of place influences the risk and mitigation of a hazard of place. Over time, this vulnerability can shift according to the risk, mitigation and the context of the environmental threat (Cutter, 1996).



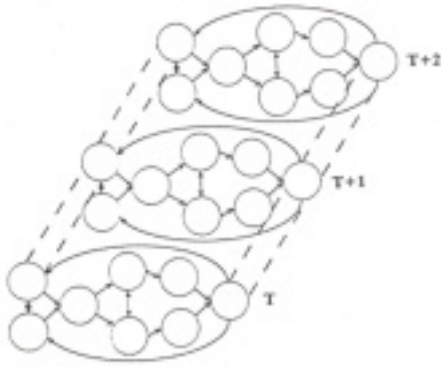


Figure 1. Hazards of place model of vulnerability as proposed by Cutter (1996).

A guiding work in understanding social vulnerability indications is Adger (1999), who differentiates two levels of vulnerability: the individual and the collective levels. The former level includes gender (women and minorities may possess less resources and experience more obstacles to recovery), ethnicity, and race (racial and ethnic minorities are disadvantaged by environmental injustice) (Cutter et. al., 2003), age (elderly are more vulnerable to be harmed) (Bergstrand et. al., 2015; Cutter et. al., 2003), and socioeconomic status (poor people are inclined to less resources and safety-nets) (Bergstrand et. al., 2015). The macro level covers the living place (urban or rural and density), accessibility to medical services, the conditions of the infrastructure (inadequate constructions can exacerbate destruction), management of land (Cutter et. al., 2003), diversification and risks of economic activities, and unemployment percentage (increased difficulty of going back to work after a calamity) (Hewitt, 2014; Cutter et. al., 2003).

Resilience. In addition, within the resilience literature, a single inclusive definition of the concept is difficult to find (Bollig, 2014). Bollig (2014) explained three ways to approach the resilience concept and referred to Brand and Jax (2007) as having a typology of resilience that includes ecological, sociological, and economic meanings. First, descriptive concepts of resilience contribute to a measurable explanation of resilience. Second, hybrid concepts strive to connect social, economic, and ecological substructures. These concepts create a stage for interdisciplinary conversations and frameworks about resilience and facilitate the collaborative analysis of social-ecological systems between social scientists, practitioners, and politicians. Lastly, normative concepts target a favoured state of resilience - sustainable treatment of natural resources, decentralised justice, the absence of poverty, adaptive learning, and shared responsibility - to be developed. In order to work with the concept of resilience from a sociological viewpoint, it is imperative to keep definitions bounded and for the discipline in question

to ask: 'resilience *of* what and *to* what?' (Bollig, 2014). Following this typology, this paper narrows down its use of the concept of resilience to social resilience, which is a descriptive concept. This allows the paper to assess resilience measurably.

Within the social resilience literature, various authors have concluded that at the essence of social resilience is the ability to respond to, absorb, adapt, and transform (Keck and Sakdapolrak, 2013; Saja et. al., 2018). These notions of the persistence of ecosystem functions, human adaptations, and social transformation are rooted in ecological systems thinking (Keck & Sakdapolrak, 2013). In their multi-layered definition of social resilience, Obrist, Pfeiffer, and Henley (2010) also incorporated this ability to cope and adjust and categorise it as a reactive capacity. However, to this definition of social resilience, researchers add the proactive ability to access economic, social, and cultural capital, controlled by power-related symbolic capital, to develop competences and thus positive outcomes (Obrist et. al., 2010). Additionally, Keck and Sakdapolrak (2013) characterise three features of social resilience. Social resilience is a dynamic process rather than a condition or object. It perceives reality in a constant flux where doubt, crisis, and change are common. Next to that, social resilience is a relational concept rather than an essentialist concept. Social entities are ingrained and influenced by their ecological, social, and institutional environments (Keck & Sakdapolrak, 2013). This agrees with Faulkner, Brown, and Quinn (2018), who stated that "resilience as an emergent property of a complex and dynamic system forged by diverse relationships between a set of resilience enhancing capacities that together contribute to enabling or constraining community resilience in different ways, depending on the context." (Faulkner et. al., 2018, p. 7). Contrary to this definition, Keck and Sakdapolrak (2013) added that social resilience is a political concept: the pursuit of resilience building and its accompanying social transformation is open to participation and power. Social education, participative decision-making, and collective change are fundamental for social resilience (Keck & Sakdapolrak, 2013).

Faulkner, Brown, and Quinn (2018) researched how to empower community resilience, for which they focused on five different capacities: leadership, community cohesion, and efficacy, attachment to place, community networks, and learning, and how their interaction can foster resilience. Leadership relates to the effective decision-making of a community when it faces transformation and its processes of creating knowledge and trust. Community cohesion and efficacy refer to the capacity and belief in undertaking challenges together. Place attachment implies the engagement of a community to adapt, to continue their lives in their valued area. However, this can also reduce resilience levels because it can create resistance for a community to leave a high-risk place. Community networks encompass the connecting relationships that help people respond as a group. Finally, as mentioned earlier, learning conveys the ability to understand and transform based on local needs and problems. They conclude

that there is no universal method to facilitate community resilience because the context of every community is different, which has an effect on the organisation of capacities, links, and causal patterns for resilience. This is a result of communities' distinctive perception of the importance of certain capacities to boost resilience, which makes resilience a complex and dynamic phenomenon. Therefore, it is imperative to look at capacities holistically and consider their overlap and correlation (Faulkner et. al., 2018). Maru et. al. (2014) added that local environmental know-how, robust social capital, and the capacity to move or change are essential for empowering social resilience.

***Confluence between Resilience and Vulnerability*.** The relationship between social resilience and social vulnerability is closely correlated in various aspects. Bergstrand et. al. (2015) found a correlation between places that are more prone to harm—which have insufficient capacities to rebound effectively—and, on the other hand, places with little vulnerability to hazards—which are rich in resources to assist recovery. Namely, resilient communities often exhibit lower vulnerability due to their ability to adapt and recover swiftly. Conversely, vulnerable communities may lack the resilience to withstand and recover from hazards. This is accredited to the logical deficiency of safety networks for anticipating and responding to disasters. Considering this, it is imperative to acknowledge the different needs of both phenomena and how resources and interventions are appropriately distributed. When resilience is low, post-disaster assistance and reconstruction schemes may be more valuable, whereas when vulnerability is high, areas may benefit more from boosting crisis preparedness (Bergstrand et. al., 2015). Maru et. al. (2014) uncover a generalised resilience/vulnerability response in situations of marginalised remote communities that experience disadvantage and poverty. They argue that resilience and vulnerability reactions overlap in some ways, but that the orientation of responses in terms of scale and period remarkably differs. Vulnerability responses lean more toward actor level and short-term span feedback, this leads to short-term and unsuitably adaptive solutions. Resilience responses tend to cover system level and long-term period answers and recognise the possibility of transformation. However, these responses also have their pitfalls and may lack the capacity of society to cope with imposed changes (Maru et. al., 2014). Therefore, Maru et. al. (2014) add to build long-term resilience responses on short-term vulnerability reactions that prevent maladaptation.

Promising Mechanisms for Disaster-Resilient Societies

To achieve this resilience, it is argued that polycentric governance, public-private-civil partnerships and citizen science are effective mechanisms to use. Before investigating how they can contribute to resilient societies, this paper discusses the concepts.

Polycentric Governance. The governance of common property and provision and management of public services by citizens (civil society), local public entrepreneurs (private sector), and public officials (public sector) is a convoluted phenomenon to study. The concept of polycentricity emerges as a promising paradigm for studying this complexity. Polycentric governance refers to a system wherein multiple centres of authority coexist and interact but also overlap (Ostrom, 2010), providing diverse channels for decision-making, resource allocation, and problem-solving. Polycentric governance embodies a departure from traditional hierarchical structures towards decentralised, networked systems. Ostrom pioneered the scholarly discourse on polycentricity, particularly in the context of managing common pool resources (Ostrom, 1990). She argued that the significance of institutional diversity should be considered in the same vein as the necessity of biodiversity and should be considered as a basis for sustainable development.

Key features characterise successful polycentric governance systems. One of these elements is decentralisation. The dispersion of governing authorities across multiple levels empowers local communities, institutions and stakeholders to make decisions tailored to their contexts and to employ local knowledge and learning processes (Andersson & Ostrom, 2008; Ostrom, 2017). These forces independently produce norms and rules within their realms. This can include families, companies, municipal governments, states, federal governments or supranational organisations (Ostrom, 2017). Another element is the adaptive capacity of polycentric governance. They possess inherent adaptiveness between decentralised and centralised modes of governance and between managing and self-organisation. This allows governing entities to respond flexibly to dynamic challenges, uncertainties, and changing circumstances (Folke et. al., 2011). Next to that decentralised, polycentric systems maintain collective choice arrangements. These mechanisms for coordination and collaboration among various centres of authority and, from the bottom up, include individuals impacted by a resource regime in the decision-making process (McGinnis & Walker, 2010; Ostrom, 2010). This, in turn, ensures coherence and synergy in governance efforts. In addition, user and resource boundaries of a specific social ecological system are present that distinguish between appropriate and non-appropriate users and resources. Furthermore, regulations concerning the appropriations and provisions are in agreement with local social and environmental situations and ensure that the costs balance the gains. Likewise, individuals are responsible for monitoring the appropriations and provision by users and the conditions of the resources. Moreover, the punishment of violations should be increased gradually as users continue to violate the rules. In addition, the right of local users to establish their own rules is acknowledged by the governing authority. Finally, the principle of nested enterprises is respected. This implies that management is arranged in multiple embedded layers when common pool resources are intimately linked to a larger social-ecological system (Ostrom, 2010).

Problems within society concerning the natural resources of social-ecological systems arise from a lack of recognition of the interdependence and complex links between social systems and ecosystems. These cross-scale correlations within the globalised social-ecological system express themselves in the economic market, biodiversity, land-use alterations and climate responses. Next to that, propellers of change, such as increasing population sizes, urbanisation, migration, new economic markets, and technological and social innovation, can thus be coupled with disturbances such as unstable financial markets, unpredictable energy prices, and environmental catastrophes. This reflects the interconnection between social and ecological systems. Polycentric governance frameworks have proven instrumental in managing these natural resources, such as fisheries, forests, and water bodies, by engaging local communities, government agencies, and non-governmental organisations in collaborative conservation efforts (Folke et. al., 2011). Furthermore, polycentric systems have mutual monitoring, learning, and adaptation instruments that improve strategies over time. Additionally, these forms of government boost innovation, adaptation, trust, common understanding, cooperation among users, learning, a decline in free riders, and more competent, unbiased, and sustainable results over various scales. Finally, regarding climate change, polycentricity helps meet the international law principle of matching problems across multiple dimensions - global, national, regional, and so on - by coupling the contributions of each level to the cross-scale problems (Ostrom, 2017).

Although polycentric governance offers significant advantages, its implementation faces certain challenges. One of these obstacles is transformability, which refers to the ability to generate untried beginnings to develop new societal behaviour and systems when economic, ecological, and social circumstances make the current structure unjustifiable (Folke et. al., 2011). Next to that, leakage between locations and leakage between markets is a problem that occurs. This means that an endeavour in one location can be moved to another location because of a climate change regulation. On the market level, this implies changes in expenditure due to constraints on activities, for example, harvesting from forests. Additionally, inconsistent policies, referring to conflicting procedures in different technology areas, for example, are obstacles to polycentric governance. Lastly, inadequate certification and free riding encumber the enforcement of polycentricity (Ostrom, 2017).

Public-Private-Civil Partnerships. There is little literature to be found about public-private-civil partnerships. The C2IMPRESS project argues that these inclusive partnerships acknowledge the complementary assets and resources of stakeholders to their ambitions to manage social, economic, and environmental threats. According to the project, the PPCP approach focuses on cooperation and shared accountability between sectors because it recognises that a single sector cannot deal with the complex

problems societies currently face in isolation. The forms of PPCP projects vary widely, from multi-stakeholder programmes to policy discussions and community forums. And so does its focus on infrastructure, education, and environmental protection. [1]

Birner and Wittmer (2006) analysed Guatemala's forest administration (Instituto Nacional de Bosque (INAB)), which is managed by professionals from the public and private sectors and civil society grouped into an independent agency. They found that issues such as political interest capture and combat corruption diminish. To achieve this, they argued that stimulating dialogue between stakeholders and the ability of private and civil society associations to manage themselves is an important element. Next, the capacity to choose competent and engaged representatives and establish a mutual understanding and vision lead to successful partnerships (Birner & Wittmer, 2006).

However, the work of the PPCP must be sustained, which can be accomplished through the support of donors and international organisations to advanced coordination between the three sectors. There are also some trade-offs that must be considered. Birner and Wittmer (2006) discussed the occurrence of delegatee drift and legitimacy drift. Delegatee drift entails the seeking of ambitions other than those the decision-makers aimed for when creating the partnership. Legitimacy drift relates to the lack of legitimacy attributed to the PPCP by the public. Furthermore, constructing the capacity of a governing PPCP is a complex process that requires the active integration of stakeholders in the rebuilding process. In this way, the ownership and interests of all sectors are developed. Additionally, the implementation of a PPCP is not enough to avoid the danger of capture of political interests. Therefore, it is imperative that stakeholders sincerely guard their organization autonomy and integrity (Birner & Wittmer, 2006).

Citizen Science (Methodology). Citizen science is an evolving and flexible approach to scientific research that actively engages public participation in the process of producing new knowledge or understanding (Robinson et. al., 2018). While the term "citizen science" has gained popularity in recent years, its roots in involving the public in scientific endeavours can be traced back centuries. One notable example is the Audubon annual Christmas Bird Count, which began in 1900 as a citizen-driven effort to track bird populations. Over the years, the number of studies, number of volunteers, and scope of data have significantly expanded (Cohn, 2008). Next to that, citizen science is not tied to a specific discipline but can be applied to diverse situations. Additionally, it facilitates the public's contribution to various fields and stimulates a collaborative and inclusive approach to scientific analysis (Robinson et. al., 2018).

Primarily, citizens have been involved in citizen science through the 'contributory' method which entails only the collecting and submitting of information by the public.

However, it is argued that a deeper involvement of citizens in research can cultivate a sense of ownership for contributors and the benefit of local know-how. These methods would be 'collaborative' or 'co-created' with participants (Robinson et. al., 2018).

This approach allows for large-scale data collections by mobilising diverse participants to contribute to scientific research. However, this can have an effect on the quality of data and should be critically controlled as the expertise of participants may differ (Bonney et. al., 2009; Cohn, 2008). Next to that the method supports public participation by citizens in scientific development and engages them in contributing to their community (Hecker et. al., 2018). On the other hand, citizen science also brings about some challenges. As already mentioned, the variability in the knowledge and skills of the participants and the methodologies used can impact the accuracy and consistency of the results. Measures such as clear data collection protocols, supplying understandable and reasonable data forms, and assistance for participants in comprehending the protocols and submission of information can help guarantee the quality of the results (Bonney et. al., 2009). Another critique that arises is the bias towards inclusion and accessibility of participation. However, Hecker et. al. (2018) argued that full inclusion should not be assumed, and the contribution of individuals from different educational backgrounds should be considered. Additionally, the costs of executing citizen science research can be high since staff must manage not only data collection and analysis but also participant support. However, Bonney (2009) argued that the amount of high-quality data that citizen science projects produce weighs down long-term costs.

Discussion: How does Polycentric Governance, Public-Private-Civil Partnerships and Citizen Science Provide Social Resilience?

The following section discusses how polycentric governance, Public-Private-Civil Partnerships and Citizen Science fundamentally contribute to or fail to contribute to the construction of social resilience for societies. As discussed, to establish social resilience, there is a need for reactive capacity and learning (Obrist et. al., 2010; Keck & Sakdapolrak, 2013; Saja et. al., 2018; Faulkner et. al., 2018). This ability to cope, adjust, learn, adapt and even transform is found within polycentric governance through its creation of decision-making, resource allocation and problem-solving mechanisms (Ostrom, 1990). Furthermore, the adaptive (Folke et. al., 2011) and mutual monitoring and learning capacities of polycentric governance (Ostrom, 2017) demonstrate its reactive capacity. Next to that, citizen science its application in various disciplines (Robinson et. al., 2018) exemplifies its capacity to adapt to different situations and to answer the question: 'resilience *of* what and *to* what?' (Bollig, 2014). PPCP does not show any characteristics that correspond to the necessity of reactive capacity for social resilience.

Next to that, Obrist, Pfeiffer, and Henley (2010) argued that the positive outcomes of social resilience are based on the capacity to exploit economic, social, and cultural capital. Only the PPCP model conforms to this element because it acknowledges the complementary assets and resources of the stakeholders.

Also, the aspect of leadership for social resilience (Faulkner et. al., 2018) is seen in polycentricity and PPCP and citizen science. Polycentric government is based on decentralisation of governing authorities and collective choice arrangement across multiple levels, which designates decision-making to local communities, institutions, and stakeholders (Andersson & Ostrom, 2008; Ostrom, 2017; McGinnis & Walker, 2010; Ostrom, 2010). PPCP contributes to this aspect by reducing political interest capture and combating corruption (Birner & Wittmer, 2006). Citizen science also corresponds to this element because it actively engages the public in producing new knowledge (Robinson et. al., 2018).

Moreover, community cohesion and efficacy (Faulkner et. al., 2018) is echoed in polycentric governance through collective choice arrangements that sustain coherence and synergy in governance efforts (Ostrom, 2010) and matching problems in international law (Ostrom, 2017). PPCP follows this feature, as seen in its cooperation and shared accountability between sectors, the diminishment of political interest capture, and combat corruption (Birner & Wittmer, 2006). Finally, citizen science shows a collaborative and inclusive approach towards the public in scientific analysis (Robinson et. al., 2018; Hecker et. al., 2018), which boosts cohesion within a society.

Furthermore, only polycentric governance, through its user and resource boundaries in a specific socio-ecological system (Ostrom, 2010), can advance the place attachment aspect of social resilience (Faulkner et. al., 2018). Next to that, community networks (Faulkner et. al., 2018) are imperative for social resilience, which polycentricity shows through decentralisation (Andersson & Ostrom, 2008; Ostrom, 2017), engagement of local communities, government agencies, and non-governmental organisations in collaborative conservation efforts to manage natural resources (Folke et. al., 2011), and collective choice arrangements (McGinnis & Walker, 2010; Ostrom, 2010). Additionally, PPCP acknowledges the complementary assets and resources of stakeholders and cooperation and shared accountability between sectors. Finally, citizen science also helps to create community networks and knowledge by employing a collaborative and inclusive approach towards stakeholders to scientific analysis (Robinson et. al., 2018).

Another aspect of social resilience entails system-level responses (Maru et. al. 2014) and the holistic approach of examining different capacities and their correlations (Faulkner et. al., 2018). Polycentricity follows this by matching problems across different scales in international law (Ostrom, 2017). PPCP acknowledges the complementary assets and resources of stakeholders and the cooperation and shared

accountability between sectors. Citizen science can then be applied to diverse situations and disciplines (Robinson et. al., 2018), allowing constructed science to incorporate various relevant fields of interest.

Social resilience also builds on local environmental know-how (Maru et. al., 2014). In polycentricity, this is reflected in the dispersion of governing authorities across multiple levels and collective choice arrangement, which empowers inclusion, local communities, institutions and stakeholders to make decisions tailored to their contexts and employ local knowledge and learning processes (Andersson & Ostrom, 2008; Ostrom, 2017; McGinnis & Walker, 2010; Ostrom, 2010). Citizen science also implements local knowledge through its collaborative and inclusive approach of stakeholders to scientific analysis (Robinson et. al., 2018; Hecker et. al., 2018). PPCP does not demonstrate any characteristics that correspond to the necessity of local environmental know-how for social resilience.

Finally, mobility, as a foundational element of social resilience (Maru et. al., 2014), is only represented in polycentric governance through its adaptive capacity to respond flexibly to dynamic challenges, uncertainties and changing circumstances (Folke et. al., 2011).

Conclusion

To respond to the intricate social-ecological problems facing societies, the social resilience framework offers an imperative approach to sustainable solutions. Nonetheless, similar to the questions that contemporary problems pose, social resilience as a response is a complex phenomenon that is closely interwoven with social vulnerability. This paper aimed to demonstrate how mechanisms such as polycentric governance, PPCP, and citizen science can advance social resilience within societies, as applied by the C2IMPRESS project. The aspects of reactive capacity, leadership, community cohesion, and efficacy, community networks, and system-level responses are found in all of these mechanisms. Exploitation of economic, social, and cultural capital is reflected only in PPCP models, and place attachment and mobility are revealed only in polycentric governance. Finally, polycentric governance and citizen science also entail characteristics of local environmental know-how.

One simple solution does not exist for constructing social resilience; thus, although these mechanisms partly answer this question, many key elements in social resilience building are not yet explored.

Gaps and Suggestions for Future Research

Polycentric governance, PPCP, and citizen science offer frameworks to improve social resilience among communities. Nevertheless, difficulties remain. Measuring

resilience and vulnerability is a difficult task considering the inherent difficulty of quantifying social losses within post-disaster cost/loss estimation reports. These intangible losses present challenges not only in their representation with physical objects but also in their measurement (Cutter et. al., 2003). Considering this difficulty, measuring the actual increase in social resilience with the implementation of the three discussed approaches becomes more challenging. This paper proposes further development of a composite resilience index that incorporates multidimensional indicators of social resilience to capture the impact of the mechanisms on them. In addition, the participatory nature of these mechanisms could also engage local knowledge to better understand their impact on social resilience.

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