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# SOCIETY AND ECOLOGY IN EUROPEAN UNION: evaluating collaborative environmental governance in the LIFE Programme through a network approach

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# SOCIETÀ ED ECOLOGIA IN UNIONE EUROPEA: la valutazione della governance ambientale collaborative del Programma LIFE attraverso un approccio di rete

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## List of abbreviations and Acronyms

CEG: Collaborative Environmental Governance

ERGM: Exponential Random Graph Models

EU: European Union

EUNIS: European Union Nature Information System

HN: Habitat Network

LIFE-CCA: LIFE Climate Change Adaptation

LIFE-CCM: LIFE Climate Change Mitigation

LIFE-ENV: LIFE Environment

LIFE-GIC: LIFE Governance and Information for the Climate

LIFE-GIE: LIFE Governance and Information for the Environment

LIFE-NAT: LIFE Nature

N2000: Natura 2000

NGO: Non-Governmental Organization

PN: Partnership Network

PTRC: Piano Territoriale di Coordinamento

SEN: Social-Ecological Network

SES: Social-Ecological System

SME: Small-Medium Enterprise

SNA: Social Network Analysis

## Summary

In the last decades, humanity takes consciousness that the quality of its life is entirely dependent on health of state of nature: emergencies that global society is fighting nowadays (*e.g.*, climate emergency and the Covid-19 pandemic) are pieces of evidence of this close connection. International institutions recognize the need to urgently take actions to protect, restore, and manage natural ecosystems, and to ensure social well-being, through the identification of shared and universally accepted principles fostering sustainability transformations. Nevertheless, the concretization of sustainability transformations in the real world requires clear strategies by decision-makers pertaining to a multi-level governance system having the role and responsibility to realize these processes. Collaboration emerges as a fundamental factor that can enhance the effectiveness of environmental governance initiatives, even if it cannot be considered a panacea solution, able to provide a general strategy that fits all social-environmental contexts where initiatives take place. In the European Union (EU), the LIFE Programme is considered the most important financial source of environmental project co-financing, allowing the concretization of collaborative environmental activities to foster sustainability transformations. Through co-funding projects proposed by partnerships of actors, about biodiversity conservation, climate change mitigation and adaptation, and the sustainable use of natural resources, the LIFE Programme aims to contribute to achieving EU environmental objectives. Thus, the analysis of governance characteristics enabled by LIFE projects allows getting a general overview of strengths and weaknesses of the collaborative environmental governance across EU countries. Therefore, the general objective of this research is to contribute to investigate how society and ecology interact within the EU-funded LIFE initiatives and, as specific research objective (i) clarify how the theoretical concept of environmental network governance can be adapted to the specific case of the EU-funded LIFE Programme, (ii) identify the network factors, features, and, consequently, statistics that better specify the emergence of collective action in LIFE projects across Europe. Addressing the specific research objectives allows to propose a measurement tool able to evaluate specific features of the collaborative environmental governance sustained by LIFE projects through a network approach that can valorize social-ecological interdependencies. Thus, thanks to the tool, it will be possible to make evident the strengths and weaknesses of the collaborative environmental governance enabled by LIFE projects.

This dissertation is composed of two parts. The first part represents the body of the dissertation, where research objectives are addressed through three studies reported as an article (Article 1) and two papers (Papers 2 and 3), after introducing critical theoretical concepts and core methodologies. Then, in part two, two additional articles (Articles A and B) report complementary studies composing the additional researches done – as co-authors – which are complementary to the body of this dissertation.

In part one, by assuming the fundamental role of collaboration in the governance of natural ecosystems, **Article 1 (*i.e., Collaborations in Environmental Initiatives for an Effective "Adaptive Governance" of Social–Ecological Systems: What Existing Literature Suggests***) reviews how and under what conditions collaborative efforts are effective. The article reviews past experiences reported in the literature to identify recommendations to improve collaborative environmental governance. The analysis highlights the importance of adopting participative approaches fostered by clear communication and transparent dialogue among stakeholders to ensure equity in the sustainability processes. Furthermore, transdisciplinary, and integrations of knowledge, practices, and perspectives emerge as key concepts allowing strategic visions that simultaneously address social and ecological challenges, concretizing effective collaborative initiatives.

Recommendations extracted from Article 1 set the bases for identifying **Paper 2 (*i.e., Collaborative environmental governance for nature and biodiversity in the EU-funded LIFE-NAT projects (2014-2020): evidence emerging in Italian protected areas)*** purposes, which verifies if collaborations fostered by LIFE-NAT projects implemented in Italy, as a case study, support the concretization of multi-level and multi-actor governance. Specifically, through the Social Network Analysis (SNA) of project partnerships, the study investigates their composition and identifies tendencies in the structure of the analyzed network using descriptive network statistics. The analysis verifies the existence of multi-level interactions between national and regional actors involved in the conservation activities through the implementation of LIFE-NAT projects but reveals low involvement of local actors. Equally, the study highlights that multi-actor partnerships are composed mainly of public actors with a reduced presence of private organizations.

**Paper 3** (***i.e., Probabilistic Network Analysis of Social-Ecological Relationships emerging from EU LIFE Projects for Nature and Biodiversity: an Application of ERGM models in the Case Study of the Veneto region (Italy))*** enlarges the field of analysis by considering both social and ecological components involved in LIFE-NAT project implementation (*i.e.,* project partners, Natura 2000 sites, and protected habitats). Therefore, it

proposes a novel approach based on network analysis aimed at analyzing interactions between and within society and natural ecosystems and characterized by statistical robustness through Exponential Random Graph Models (ERGM). The study, focused on LIFE-NAT projects implemented in Veneto region (Italy), evaluates the effectiveness of the collaborative environmental governance catalyzed by LIFE-NAT projects considering social and ecological elements. Results show that LIFE-NAT projects catalyze polycentric governance but fail in concretizing multi-actor and multi-level governance. Conversely, it demonstrates their capacity to sustain ecological connectivity and synergies across freshwater, land, and marine habitats.

Concluding remarks highlight the relevance of studies and theoretical contributions to the scientific knowledge, studies limitations, and policy recommendations for policymakers and practitioners proposing practical tips to improve the collaborative environmental governance fostered by LIFE projects.

In Part 2, **Article A (*i.e., Intermediary organisations in collaborative environmental governance: evidence of the EU-funded LIFE sub-programme for the environment (LIFE-ENV)*)** reports the first explorative network analysis of LIFE projects, setting the bases of this research. Finally, **Article B (*i.e., Intermediary Organizations in Nature Conservation Initiatives: The Case of the EU-Funded LIFE Programme*)** represents a general overview of LIFE-NAT project partnerships, becoming a source for comparisons for papers 2 and 3.

## Sommario

Negli ultimi decenni, l'umanità ha preso consapevolezza che la qualità della sua stessa vita è completamente dipendente da quella della natura: emergenze che la società globale sta oggi affrontando (es., emergenza climatica e Pandemia da Covid-19) sono evidenze di questa stretta connessione. Le istituzioni internazionali hanno riconosciuto il bisogno di agire urgentemente per proteggere, ripristinare e gestire gli ecosistemi naturali in modo tale da assicurare un benessere sociale, identificando dei principi condivisi e universalmente accettati che incentivano delle trasformazioni verso la sostenibilità. Nonostante ciò, la concretizzazione di trasformazioni sostenibili nel mondo reale necessita di strategie chiare adottate dai decisori politici, appartenenti a un sistema di governance multi-livello, che hanno il ruolo e la responsabilità di realizzare questi processi. La collaborazione emerge come una componente fondamentale che è capace di aumentare l'efficacia delle iniziative derivate da una governance ambientale collaborativa, anche se non può essere considerata una soluzione universale capace di fornire una strategia generale che si adatti a tutti i contesti socio-ecologici nel quale tali iniziative hanno luogo. Nel contesto dell'Unione Europea (UE), il programma LIFE è considerato la più importante fonte di risorse finanziarie di progetti ambientali co-finanziati, che permettono la concretizzazione di attività ambientali collaborative tra i Paesi europei. Attraverso il co-finanziamento di progetti proposti da partenariato di attori, relativi alla conservazione della biodiversità, la mitigazione e l'adattamento ai cambiamenti climatici e all'uso sostenibile delle risorse, il Programma LIFE vuole contribuire al raggiungimento degli obiettivi ambientali dell'UE. Per questo motivo, l'obiettivo principale di questa ricerca è di investigare in che modo la società e l'ecologia interagiscono nel contesto delle iniziative supportate dal Programma europeo LIFE, che è stato declinato nei seguenti obiettivi specifici: (i) chiarire come il concetto teorico di governance ambientale di rete possa essere adattato al caso specifico del Programma Europeo LIFE, (ii) identificare i fattori, caratteristiche di rete, e conseguentemente, le statistiche che meglio specificano l'emergere di azioni collettive nei progetti LIFE in Europa. Attraverso il raggiungimento degli obiettivi specifici di ricerca è possibile proporre uno strumento di misurazione capace di valutare specifiche caratteristiche della governance ambientale collaborativa sostenuta dai progetti LIFE, attraverso un approccio di rete che valorizzi le relazioni socio-ecologiche.

Questa tesi è composta da due parti. La prima parte rappresenta il corpo della tesi, dove gli obiettivi di ricerca sono raggiunti attraverso tre studi riportati come un articolo (Articolo 1) e due papers (Papers 2 e 3), dopo

l'introduzione dei concetti teorici chiave, le metodologie fondamentali e gli obiettivi di ricerca. Successivamente, nella parte due, due articoli aggiuntivi (Articoli A e B) riporta degli studi complementari che compongono delle ricerche aggiuntive fatte – come co-autrice – che sono complementari al corpo di questa tesi.

Nella prima parte, assumendo il ruolo fondamentale della collaborazione nella governance degli ecosistemi naturali, l'**Articolo 1 (*i.e., Collaborazioni in Iniziative Ambientali per una "Governance Adattiva" Efficace dei Sistemi Socio-Ecologici: Cosa Suggerisce la Letteratura Esistente*)** esamina come e in quali condizioni gli sforzi collaborativi sono efficaci. L'articolo esamina le esperienze passate riportate nella letteratura scientifica per identificare delle raccomandazioni capaci di migliorare la governance ambientale collaborativa. L'analisi sottolinea l'importanza fondamentale di adottare degli approcci partecipativi che vengano supportati da una chiara comunicazione e dialogo trasparente tra i diversi portatori di interesse per poter assicurare equità nei processi verso la sostenibilità. Inoltre, multidisciplinarietà e integrazioni di sapere, pratiche e prospettive emergono come concetti chiave che incentivano visioni strategiche capaci di affrontare simultaneamente sfide sociali ed ecologiche, concretizzando delle efficaci iniziative collaborative.

Le raccomandazioni derivate dall'Articolo 1 hanno posto le basi per l'identificazione degli obiettivi del **Paper 2 (*i.e., La governance ambientale collaborativa per la natura e la biodiversità nei progetti europei LIFE-NAT (2014-2020): evidenze che emergono dalle aree protette italiane*)**, finalizzato a verificare se le collaborazioni sostenute dai progetti LIFE-NAT implementati in Italia, come caso studio, hanno supportato la concretizzazione di una governance multi-attore e multi-livello. Nello specifico, attraverso la Social Network Analysis (SNA) dei partenariati di progetto, lo studio investiga la loro composizione e identifica le tendenze strutturali del network analizzato mediante delle statistiche descrittive di network. L'analisi verifica l'esistenza di interazioni multilivello tra attori nazionali e regionali che sono coinvolti in attività di conservazione attraverso l'implementazione di progetti LIFE-NAT, ma rivela un basso coinvolgimento degli attori locali. Allo stesso modo, lo studio sottolinea che i partenariati multi-attore sono composti prevalentemente da attori pubblici caratterizzati da una ridotta presenza di attori privati.

Il **Paper 3 *(i.e., Analisi Probabilistica di Rete delle Relazioni Socio-Ecologiche che emergono dal Programma Europeo LIFE per la Natura e la Biodiversità: un'Applicazione di modelli ERGM nel Caso Studio della regione Veneto (Italia))*** estende il campo di analisi considerando sia componenti sociali che ecologiche coinvolte

nell'implementazione di progetti LIFE-NAT (ovvero partners di progetto, siti Natura 2000 e habitat protetti). Infatti, esso propone un nuovo approccio basato sulla network analysis capace di analizzare le interazioni tra e all'intero di società e ecosistemi naturali, caratterizzato da una robustezza statistica mediante l'uso di Modelli di Grafi Casuali Esponenziali (ERGM). L'analisi, focalizzata sui progetti LIFE-NAT implementati nella regione Veneto (Italia), valuta l'efficacia della governance ambientale collaborativa catalizzata dai progetti LIFE-NAT considerando sia elementi sociali che ecologici. I risultati mostrano che i progetti LIFE-NAT catalizzano una governance policentrica ma falliscono nella concretizzazione di una governance multi-attore e multi-livello. D'altra parte, essa dimostra la loro capacità di sostenere una connettività ecologica e le sinergie tra habitat d'acqua dolce, continentali e marini.

Le conclusioni sottolineano la rilevanza degli studi e i contributi teorici apportati al sapere scientifico, le loro limitazioni e delle raccomandazioni per decisori pubblici e operatori del settore che propongono dei suggerimenti pratici per migliorare la governance ambientale collaborativa mediante progetti LIFE.

Nella Parte 2, l'**Articolo A (*i.e., Organizzazioni intermediarie nella governance ambientale collaborative: evidenze dal sotto-programma LIFE per l'ambiente (LIFE-ENV))*** riporta la prima analisi di rete esplorativa di progetti LIFE, ponendo le basi di questa ricerca. **L'Articolo B (*i.e., Organizzazioni intermediarie nelle iniziative di conservazione della natura: il caso dei progetti europei LIFE*)** rappresenta una panoramica generale dei partenariati di progetti LIFE, diventando una risorsa per confronti dei papers 2 e 3.

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# Part 1: Body of Dissertation

# Chapter 1: General Introduction to the Ph.D. research

This chapter aims to introduce the background of this research, elucidating critical theoretical concepts, problems, and challenges to be faced, the core methodology, and the application area as the basis of this study. Then, it presents the research objectives and the structure of this study, evidencing the logical flow leading to the research evolution.

## 1.1 Research background and problem statement

### 1.1.1 Theoretical key concepts

Environmental problems that society needs to face nowadays also represent social problems: ecological emergencies such as biodiversity degradation, water, and air pollution, land and sea overexploitation, and climate change impact on human well-being and health. For example, climate change increases the possibilities of flooding, droughts, scarcity of agricultural production, inducing famines which could provoke immigration or war (Sharifi *et al.,* 2021; Balsari *et al*., 2020; Selbi *et al.,* 2019). Current emergencies demonstrate that environmental problems determine adverse effects on society, which is characterized by individual and collective values, perceptions, knowledge, relationships, rules, *etc.* (Folke *et al.,* 2016). Therefore, environmental challenges cannot be separated from community values, equity, and social justice (Berkes, 2017; Folke *et al*., 2016). Moreover, in the last decades, humanity takes consciousness that the quality of its life is entirely dependent on the state of health of nature. Nevertheless, society can exert positive or negative effects on nature through its actions, improving or degrading natural ecosystems (Folke *et al*., 2016). Accordingly, in the scientific literature emerge multiple theoretical concepts highlighting in different ways and with different perspectives the need to recognize the solid mutual interdependencies between nature and society, such as the Social-Ecological System concept (Colding and Barthel, 2019), the Ecosystem Services framework (Costanza *et al*., 2017), and the One Health Approach (Davis and Sharp, 2020).

The ***Social-Ecological System (SES)*** concept describes our world as a constantly evolving system characterized by complexity and unpredictability composed of two equal sub-systems, the social and the ecological ones, which interact in multiple and different ways (Colding and Barthel, 2019; Folke *et al.*, 2016). The SES is intrinsically conceptualized as an open system, susceptible to social and ecological changes due to, *e.g*., market, population growth, and political changes (Colding and Barthel, 2019), so it is related to three

attributes: resilience, adaptability, and transformability (Walker *et al.,* 2004), which evidence how social-ecological challenges are constantly changing ad evolving through both space and time (Bodin, 2017). The introduction of such a concept in the scientific literature through the descriptive framework proposed by Berkes and Folke (1998) allows the development of multiple frameworks aimed at analyzing interactions between society and natural ecosystems, which highlights in numerous and various ways, that society is part of the biosphere, and it is entirely dependent on it (Folke *et al*., 2016).

The ***Ecosystem Services*** framework makes evident the dependence of human prosperity on natural ecosystems with the identification of four groups of services, called ecosystem services, which sustain human well-being physically, psychologically, culturally, and economically (*i.e*., supporting, provisioning, regulating, and cultural ecosystem services) (Costanza *et al.,* 2017; Häyhä and Franzese, 2014). Ecosystem services are characterized by interdependencies and by the maintenance of a delicate balance which, if perturbated by individuals for the satisfaction of their needs, can cause cascade effects with different impacts on people, both positive and negative (*e.g*., Clark *et al*., 2017; Anderson *et al*., 2011). According to this view, from ecosystem services, people get benefits consciously or unconsciously, directly or un-directly (Costanza *et al*., 2017), but at the same time, unsustainable behaviors cause the loss of such services. Consequently, they foster the emergence of environmental problems and challenges to be addressed by society, which can have numerous and unpredictable effects both on the local and global levels due to ecosystem connectivity (*e.g*., de Araujo Barbosa *et al.,* 2016; Bodin, 2017; Bodin *et al*., 2019).

Recently, society has experienced global effects of ***social-ecological challenges*** during the Covid-19 pandemic, strengthening the vision proposed by the ***One Health*** approach, demonstrating that human, animal, and ecosystem health are entwined (Davis and Sharp, 2020). From the One Health approach, in 2019, during the "*One Planet, One Health, One Future*" global conference, emerge multiple commitments to overcome systemic policy and social barriers to reach a global sustainability transformation, which highlights the need to adopt integrative, participative, adaptive and holistic global strategies to be transferred through policies able to concretize international commitments through sustainable local transformations (Gruetzmacher *et al.,* 2021). From these perspectives arises the view that natural ecosystems can provide benefits in dependence on how people behave, especially those who manage human processes from an organizational and institutional point of view (Asah *et al.,* 2014). This vision evidences the need to deepen

how humanity manages natural systems and what are the more effective approaches to define good practices beneficial to face emerging needs caused by the current environmental and social crises that society has to face (Bodin, 2017; Mistry *et al*., 2016).

Managing and solving social-ecological challenges require a new approach characterized by participation and integration, where researchers, managers, and stakeholders share their resources and skills to identify novel solutions (Berkes, 2017, Folke et al., 2005) through collective actions, meaning "*processes that involve sharing experiences and engaging in collective deliberation*" (Bodin, 2017; p. 2). From this perspective raises the ***governance*** concept, which mainly differs from the government concept because of the inclusion of civil society actors (Kjaer, 2004). Governance can be defined as "self-organizing, inter-organizational networks characterized by interdependence, resource exchange, rules of the game, and significant autonomy from the state (Rhodes, 1997). Stoker (1998) identified five key features of governance that distinguish it from the government: (i) institutions are both inside and beyond the government; (ii) responsibilities are shared among public and private actors to face social and economic issues; (iii) actors involved in collective actions are interdependent; (iv) actors create a self-governing network to reach objectives; (v) actors can reach objectives without the use of government authority. This perspective clarifies the fundamental role played by both public and private actors in facing problems, uncertainties, and changes that characterize social-ecological challenges (Lemos and Agrawall, 2006).

In particular, focusing on an environmental perspective, ***environmental governance*** can be conceptualized as the "*set of regulatory processes, mechanisms, and organizations through which political actors influence environmental actions and outcomes*" (Lemos and Agrawall, 2006). In other words, it refers to how society identifies and reaches goals related to environmental management and challenges. Consequently, it includes instruments, rules, and processes (Driessen *et al.,* 2012) and social norms and organizations (Chaffin et a., 2014) that foster decisions and implementations. To date, environmental governance has been articulated in several new arrangements. In particular, considering social-ecological interdependencies, this research wants to deepen especially **adaptive governance** and **network governance** (Folke *et al.,* 2005). The two approaches can be considered strictly interrelated: adaptive governance and network governance, respectively, constitute the theoretical framework and the practical approach able to face challenges affecting SESs (Erntson *et al.,* 2010).

Specifically, the terminology ***adaptive governance*** refers to an emergent form of environmental governance focused on managing uncertainties and complexities characterizing SES. Adaptive governance can be seen as the set of processes able to create conditions for shared rules, collective actions, and coordination of activities by which people share power and make decisions to achieve or maintain the resilience of SES (Folke *et al.,* 2005). It is possible to define adaptive governance as the result of interactions between actors, networks, organizations, and institutions aimed at facing environmental challenges (Chaffin *et al*., 2014). It is recognized as a helpful approach to overcoming barriers established by global environmental challenges, such as the weak effectiveness of centralized government via top-down regulations and the scarcity of coordination among multiple actors involved in local forms of governance (Andriollo *et al.,* 2021). Thus, adaptive governance implies collaboration operationalized by coordination, social learning, knowledge integration, trust building, and conflict resolution (Olsson *et al.,* 2007; Folke et al., 2005). This requires network building and information sharing, especially among different types of actors, to foster the collective learning process able to promote the identification of shared solutions to achieve adaptation, which means the capacity to change as a result of external forces and stresses (Ernston *et al*., 2010).

Social networks can enhance collective governance by facilitating the generation and diffusion of knowledge, the mobilization, and allocation of resources, the identification of common rules among different stakeholders involved, and the resolution of conflicts. Meanwhile, the network structure can affect stakeholders' behaviors and, consequently, the effectiveness of governance (Bodin and Crona, 2009). Following this background, ***network governance*** has been defined as "*a stable articulation of mutually dependent, but operationally autonomous factors (…) who interact through conflict-ridden negotiations that take place within an institutionalized framework of rules, norms, shared knowledge and social imaginaries (…) and contribute to the production of public values*" (Sørensen and Torfing, 2005). Social networks are characterized by interdependency, and consequently, they imply dialogue between different typologies of actors and the identification of shared solutions to achieve objectives, overcoming possible conflicts which can arise from different perspectives, needs, and values (Andriollo *et al*., 2021; Pisani *et al*., 2020). At the same time, networks help spread novel solutions, ideas, and best practices emerging from local experiences to a broader public in a larger geographic area. In this way, they can contribute to improving the more comprehensive systemic change in society through scaling out and scaling up processes (Loorbach *et al.,* 2020; Moore and Westley, 2011).

### 1.1.2 Problems and challenges to be faced

Adopting a broader perspective, network governance and adaptive governance characteristics allow us to consider them parts of the collaborative environmental governance concept, which assumes that ***collaboration*** is essential in governance processes to address environmental challenges (Bodin, 2017). Nevertheless, despite the existence of several examples demonstrating positive outcomes of collaborative efforts in environmental governance (*e.g*., Martini *et al.,* 2017; Calvet-Mir *et al*., 2015; Davies and White, 2012), collaboration cannot be considered a panacea solution because of both internal and external limits characterizing the governance concept and their implications in the collaborative efforts, making collaboration expensive both in terms of time and resource allocation, and challenging to maintain (Bodin, 2017; Bodin *et al*., 2016; Guerrero *et al*., 2015).

From an internal perspective, governance processes could be affected by the inadequacy of legitimacy if it is not sufficiently supported by the local community. At the same time, it enlarges the responsibility of governance activities favoring a shared environmental responsibility, which, if not adequately designed, creates ambiguities on roles and responsibilities played by every actor involved, causing blame avoidance and scapegoating (Lemos and Agrawall, 2006). Therefore, emerging forms of collaborative governance must be recognized by legal processes and legitimized by existing governance structures through the devolution of some power to networks that progressively transit from informal to institutional, allowing people to exert their role in decision-making processes (Chaffin *et al*., 2014). From an external perspective, governance effectiveness entirely depends on the specific features of the sociocultural and natural contexts where environmental actions will be implemented (Dressel *et al*., 2018; Collof *et al.,* 2017; Folke *et al*., 2016; Chaffin *et al*., 2014). On one side, it is fundamental to analyze how the social, cultural, and political contexts may influence the implementation of collective actions. Consequently, the supposed transformations are fostered by learning processes (Holzer *et al.,* 2019; Gorddard *et al*., 2016). On the other side, the analysis of the ecological background, the specific features and components of the natural capital, and the most pressing drawbacks allow for better specifying the intervention scale and working area (Dressel, 2018). Furthermore, the governance capacity to fit with ecological characteristics affects the ability to manage natural ecosystems (Bodin, 2017) effectively. Specifically, the scientific literature highlights three types of institutional fit that

governance must consider to be effective: the ecological fit, the social fit, and the social-ecological fit (Epstein *et al*., 2015).

***Ecological fit*** refers to the need to match institutions with characteristics of environmental problems they aim to face, requiring the alignment between the spatial, temporal, and functional aspects of ecosystems and institutions (Folke *et al*., 2007). ***Social fit*** refers to the need to transpose group interests, values, beliefs, and psychological needs in governance interventions (De Caro and Stokes, 2013). ***Social-ecological fit*** highlights that institutions succeed when they are designed to transversally align with both the social and ecological peculiarities of society and nature, requiring the identification of particular institutional arrangements able to contribute to better social and ecological results (Epstein *et al*., 2015).

Operatively, focusing on effective collaborative arrangements fostered through collaborative environmental governance, Guerrero *et al.* (2015) underline three social-ecological fit challenges concerning interdependencies between society and nature. The first refers to interconnectivity among actors who manage shared natural resources. If they act independently and without any form of coordination, especially across institutional borders, they can lead to the overexploitation of natural resources. Another challenge refers to the connectiveness among natural components and the possibility that an intervention could provoke cascade effects among interconnected systems. The third one refers to the term "scale," intended as jurisdictional scale, and considers the presence of multiple actors who act at different levels; consequently, scale mismatches arise when actions are implemented only at one jurisdictional level.

Even if several theoretical approaches that highlight mutual interdependence between society and nature, clearly identifying social-ecological fit challenges, have been developed in the last years, methodologies able to quantitatively study social-ecological interdependencies to evaluate the effectiveness of collaborative environmental governance are still reduced (Bodin *et al.,* 2019; Bodin and Tengö, 2012). Therefore, it is fundamental to propose new approaches to identify what typologies of collaborative interactions can get positive results in managing natural resources (Bodin and Tengö, 2012). Furthermore, developing tools able to measure the complex patterns of the social-ecological features and interdependencies is of paramount importance because if adjusted to the real needs and problems of the contexts where collective actions will take place, they can measure their socio-ecological fitness and, consequently, identify improvements which increase their effectiveness (Bodin *et al*., 2016; Guerrero *et al.,* 2015).

### 1.1.3 Core methodology

Network approaches based on ***Social Network Analysis (SNA)*** offer a valuable solution to disentangle intangible relationships between and within social and ecological systems (Bodin and Tengö, 2012). This is why SNA represents the core methodology used in this research. SNA is the study of relations among connected entities through edges that constitute the network. It can help to evaluate the effectiveness of governance initiatives by analyzing the structure of a social network and identifying structural patterns reflecting governance performances and social behaviors (Borgatti *et al*., 2013). SNA, for example, can detect bridging relations, central actors, or the tendency of homophily or heterophily, which impact the effectiveness of collaborative environmental governance (Bodin and Crona, 2009). Additionally, when SNA allows the network analysis of social-ecological connections, it makes it possible to study the social-ecological fit, assessing if governance initiatives align with the biophysical contexts where they act (*e.g.,* Guerrero *et al*., 2015).

Bodin and Tengö (2012), with the development of the ***Social-Ecological Network (SEN)*** approach, propose a tool able to identify what relations connect society and nature formally and to link them to social-ecological fit challenges. This tool can be considered a first step to identifying relational characteristics able to operationalize network governance activities positively. SENs are tools able to represent SES as a set of nodes and links (Bodin *et al*., 2019; Bodin and Tengö, 2012). Therefore, networks constituting collective environmental governance structures are formed not only by social actors but also by natural components where the intervention occurs (Bodin *et al*., 2019). An SEN comprises two types of nodes: social and ecological nodes representing both specific species or actors and more aggregated forms or phenomena. Simultaneously links show the interdependencies established among nodes, such as collaboration or competition (Bodin *et al*., 2019; Bodin and Tengo, 2012). Connections could represent social-to-social relations, ecological-to-ecological relations, and social-ecological relations (Bodin and Tengö, 2012). Multiple collective environmental actions are analyzed with evaluations based on the SEN approach, such as the analysis of the management of large-scale biodiversity conservation (*e.g*., Guerrero *et al.*, 2015), fishery management (*e.g.,* Barnes *et al*., 2019; Alexander *et al.,* 2017), land-sea interactions (*e.g*., Pittman and Armitage, 2017), forest management (*e.g.,*Bodin *et al*., 2016; Bodin and Tengo, 2012), river restoration (*e.g.,* Sayles and Baggio, 2017) and disaster management (*e.g*., Bodin and Nohrstedt, 2014).

Even if network approaches demonstrate their suitability in analyzing social-ecological relations affecting the effectiveness of collaborative environmental governance, the statistical validation of results obtained through SNA is challenging (Bodin *et al*., 2016). This is motivated because network approaches intrinsically imply the existence of dependencies between variables, so it is illogical to use standard statistical methods to assume independence between variables (Lusher *et al*., 2013). Nevertheless, SNA offers multiple descriptive statical measures helpful in exploring network tendencies, such as density, degree centrality, betweenness centrality, and clustering coefficient (Borgatti *et al*., 2013). Such network tendencies could be validated rigorously through an alternative statistical approach recently proposed by Bodin *et al*. (2016), which relies on ***Exponential Random Graph Models (ERGM).*** ERGMs are a class of models able to simultaneously verify the existence or absence of specific network configurations, giving them a parameter estimate and a standard error as conventional statistical methods (Lusher *et al*., 2013). Such an approach allows the identification of innovative ways of studying social-ecological interactions through SEN, increasing our understanding of structures affecting governance effectiveness (Bodin *et al*., 2016). Such advances demonstrate that the SEN approach can be improved by considering new typologies of interactions which can clarify the many facets of collaboration that at present are not reported in the scientific literature and identify what collaborative processes should be encouraged to achieve effectiveness in the collaborative environmental governance (Sayles *et al*., 2019; Bodin *et al.,* 2016; Guerrero *et al*., 2015).

### 1.1.4 Application area

In this research, the study of social-ecological interactions affecting collaborative environmental governance is delimited to the European contexts, through the analysis of the LIFE Programme and its implementation in the European countries, especially across the Natura 2000 network.

The ***LIFE Programme*** is the funding tool of EU for the environment and climate action (https://cinea.ec.europa.eu/life_en). Since 1992, the LIFE Programme represents one of the most important opportunities offered by the European Union (EU) to concretize collaborative environmental governance, specifically focused on environmental purposes through the implementation of LIFE projects across the EU countries, proposed and executed by partnerships of actors (R. (EU) 1293/2013). The Programme co-founds projects aimed contributing to improve biodiversity conservation and restoration, and to develop, identify

and diffuse innovations and good practices to face climate change and to enhance the sustainable use of natural resources.

Its structure, indeed, provides opportunities for the concretization of collaborations between different actors characterized by differences in needs and interests but sharing common and forward-looking environmental objectives by creating partnerships that propose project activities to be co-founded by the Programme (*e.g.,* Rigo *et al.,* 2022; Pisani *et al*., 2020). As a result, partnerships co-founded by the LIFE Programme could be composed of a multitude of stakeholders comprising the environmental governance, which fosters public-private partnerships (Lemos and Agrawall, 2006) to reach relevant environmental objectives through the replication of good practices or implementation of innovative solutions in multiple environmental priorities (*e.g.,* climate adaptation and mitigation, nature conservation, sustainable use of natural resources). Even if the LIFE Programme is susceptible to revisions and updates constituting different LIFE programming periods (LIFE I: 1992-1995, LIFE II: 1996-1999, LIFE III: 2000-2006, LIFE+: 2007-2013, LIFE 2014-2020, LIFE 2021-2027), this research is mainly focused on relationships emerged in the last programming period (2014-2020), which co-funded 1059 LIFE projects and it is characterized by the presence of two sub-programmes, each of them constituted by three priority areas:

● Sub-programme for the Environment

- Nature and Biodiversity (LIFE-NAT)

- Environment and Resource Efficiency (LIFE-ENV)

- Information and Governance (LIFE-GIE)

● Sub-programme for Climate Action

- Climate Change Adaptation (LIFE-CCA)

- Climate Change Mitigation (LIFE-CCM)

- Information and Governance (LIFE-GIC)

Specifically, the research focuses on ***LIFE-NAT*** projects which aim to protect and restore biodiversity across the EU territory, focusing mainly on protected species and habitats specified by the Habitat Directive

(92/43/EEC), which establishes a network of EU protected areas called Natura 2000. Accordingly, specific objectives of the priority area Nature and Biodiversity aim to (i) contribute to the development and implementation of EU biodiversity policies, (ii) support the concretization, development, and management of the Natura 2000 network, and (iii) improve knowledge for monitoring biodiversity quality across the EU territory and identify human pressures affecting nature and biodiversity quality (R. (EU) 1293/2013, art.11). Therefore, LIFE-NAT projects are specifically designed to enhance of EU biodiversity governance, representing the only EU fund which directly allocates resources to implement conservation activities in Natura 2000 sites (Hermoso *et al*., 2017).

***Natura 2000 network (N2000)*** represents the cornerstone of the EU efforts to preserve nature and biodiversity, becoming the largest network of protected areas in the world, covering 18% of the EU land surface and about 8% of the EU marine area (Campagnaro *et al*., 2019; Hermoso *et al*., 2017). It is constituted by core areas fundamental for the existence of rare or threatened species identified by the Habitat Directive, which are called N2000 sites (92/43/EEC). During the 30 years of its life, N2000 has achieved fundamental advances in collaborative environmental governance through, *e.g*., (i) a common legal framework based mainly on the Birds Directive (Directive 2009/147/EC) and Habitat Directive (Directive 92/43/EEC), (ii) shared monitoring schemes and standardized data across EU countries, (iii) mechanisms able to foster bottom-up initiatives through the proactive role of public participation, and (iv) common funding mechanisms (Hermoso *et al*., 2022; Campagnaro *et al*., 2019). Nevertheless, N2000 needs to overcome some limitations, related namely to (i) the effective concretization of the N2000 network (*e.g*., insufficient financial resources, heterogeneous policy enforcement across N2000, high variability and uniqueness of EU territories to be protected by a common legal framework for all EU countries), (ii) the genuine involvement of local stakeholders (*e.g.,* limited engagement of the local community in N2000 conservation activities, the resistance of local stakeholders to support N2000 initiatives), (iii) the concretization of social-ecological connectivity (*e.g.,* insufficient coordination between N2000 managers, limited physical and ecological coherence) (Hermoso *et al*., 2022; Campagnaro *et al*., 2019). Additionally, the N2000 network must face emerging challenges like climate change and integrate conservation with adaptation and mitigation efforts (de Koning *et al*., 2014). Representing suitable arenas that need to meet directly and urgently social-ecological fit challenges more evident than in other contexts, N2000 sites represent opportunities to valorize bottom-up activities that can integrate the top-down conservation efforts made by EU through N2000,

fostering local sustainability processes. Such processes, if replicated, could be transposed at supra-national levels contributing to global sustainability transformations required to face current social-ecological challenges (Hermoso *et al*., 2022; Loorbach *et al*., 2020).

**1.2 Dissertation objectives and structure**

This research aims to contribute to improving the knowledge related to Goal 17 of the Sustainable Development Goals – Partnership for the goals – and, in particular, target 17.17 "*Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships*".

The general objective of this research is to investigate in what way society and ecology interact within the EU-funded LIFE initiatives. Specifically, the research aims to design and propose a measurement tool to evaluate specific features of the environmental network governance in the EU-funded LIFE Programme through a network approach that can valorize social-ecological interdependencies.

Specifically, the research is articulated with two specific objectives:

1. Clarify how the theoretical concept of environmental network governance can be adapted to the specific case of the EU-funded LIFE Programme

2. Identify the network factors, features, and, consequently, statistics that better specify the emergence of collective action in LIFE projects across Europe.

Research objectives are addressed through articles (fig.1.1) reported in Chapters 2, 3, and 4, where they are written in their original version. In them, I have responsibility as the main author.

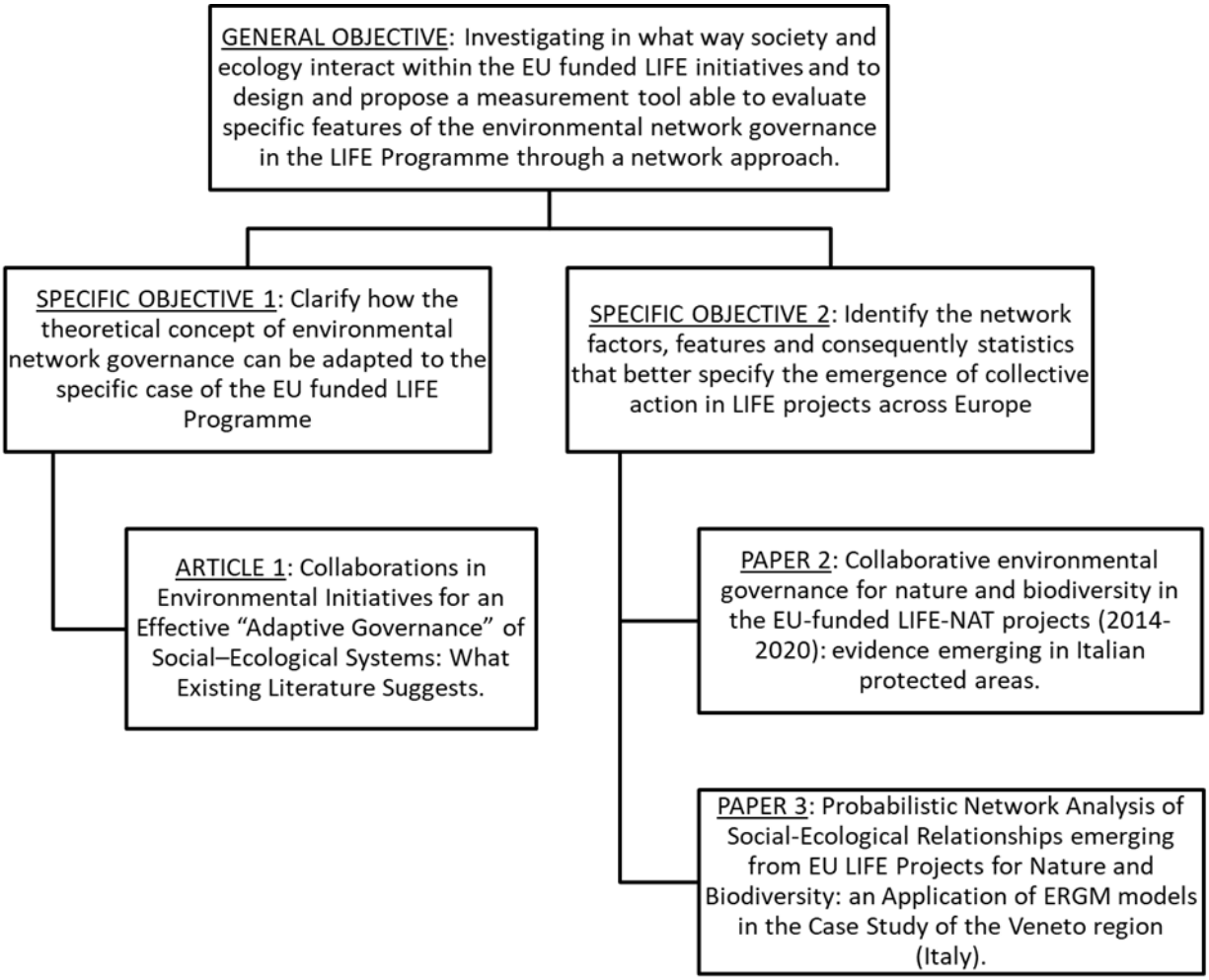


*Fig.1.1: Research structure*

The following paragraphs provide a short presentation of articles giving a general overview of the logical evolution of this research.

Chapter 2 - Article 1: ***Collaborations in Environmental Initiatives for an Effective "Adaptive Governance" of Social–Ecological Systems: What Existing Literature Suggests***.

Article published in "*Sustainability*" (Andriollo *et al*., 2021). https://doi.org/10.3390/su13158276 by Andriollo Elena, Caimo Alberto, Secco Laura, Pisani Elena.

Moving from the scientific literature on the evaluation of environmental projects and programs, this study reviews experiences to identify how and under which conditions collaborations in environmentally sustainable projects are considered effective for the adaptive governance of SES (specific objective 1). Through a systematic literature review, it analyzes articles selected through specific queries on the SCOPUS database and published from 2004 to 2020.

Chapter 3 - Paper 2: ***Collaborative environmental governance for nature and biodiversity in the EU-funded LIFE-NAT projects (2014-2020): evidence emerging in Italian protected areas.***

Paper submitted to "*Journal of Rural Sciences*" RURAL-D-22-00355 by Andriollo Elena, Caimo Alberto, Secco Laura, Pisani Elena.

This paper, assuming collaboration instrumental for the catalyzation of effectiveness in environmental governance, aims to verify if the LIFE Programme can sustain collaborations to manage protected areas through a multi-actor and multi-level governance approach (specific objective 2). Taking as a case study all LIFE-NAT Italian projects co-funded in the 2014-2020 programming period, the explorative analysis focuses on LIFE-NAT project partnerships through SNA descriptive network statistics.

Chapter 4 - Paper 3: ***Probabilistic Network Analysis of Social-Ecological Relationships emerging from EU LIFE Projects for Nature and Biodiversity: an Application of ERGM models in the Case Study of the Veneto region (Italy).***

Paper submitted to "*Environmental Science and Policy*" ENVSCI-D-22-01919 by Andriollo Elena, Secco Laura, Caimo Alberto, Pisani Elena.

This paper aims to propose a robust novel application of a network methodology based on ERGMs that could contribute to advancements in analyzing social-ecological relationships (specific objective 2). Explicitly focusing on LIFE-NAT projects implemented in the Veneto Region (Italy) financed in the last programming period (2014-2020), and through formulating four research hypotheses, we analyze social-to-social, social-ecological, and ecological-to-ecological relationships that emerged through LIFE-NAT projects implemented in N2000 sites.

This dissertation is a compilation of papers subdivided into two parts (*i.e.,* Part 1 and Part 2). Part 1 comprises this introduction (Chapter 1) and the three documents directly addressing research objectives (Chapters 2, 3, and 4). Finally, it concludes with final remarks. Part 2 proposes two articles (*i.e.,* Article A and Article B) complementary to this research in which I have collaborated in analyzing data and writing.

Article A (*i.e.,* ***Intermediary organisations in collaborative environmental governance: evidence of the EU-funded LIFE sub-programme for the environment (LIFE-ENV)*** - Pisani *et al*., 2020) represents the first

exploratory network analysis of LIFE projects through SNA. The study puts in evidence that network analysis can be considered a suitable and relevant tool for understanding the evolution of network governance and underlines the need to go further in the structural analysis of partnerships, becoming the starting point of network analyses focused on LIFE projects.

Article B *(i.e., **Intermediary Organizations in Nature Conservation Initiatives: The Case of the EU-Funded LIFE Programme*** - Rigo *et al*., 2022) present a general overview of collaborative tendencies in LIFE-NAT projects implemented across EU countries during the last programming period (2014-2020). Reporting a general overview of LIFE project partnership compositions focused on biodiversity conservation and restoration in the EU territory, it represents a valuable source of knowledge for papers 2 and 3.

Author contributions are specified in table 1.1.

*Table 1.1. Contributions of authors for the development of the dissertation's papers*

| | Main papers | | | Complementary papers | |
|---|---|---|---|---|---|
| Responsibility - Task | Article 1 | Paper 2 | Paper 3 | Article A | Article B |
| Overall responsibility | **E.A.** | **E.A.** | **E.A.** | E.P. | E.P., A.R. |
| Conception and design | **E.A.**, E.P., L.S. | **E.A.**, E.P., L.S. | **E.A.**, E.P., A.C. | E.P. | A.R., E.P. |
| Methodology design | **E.A.**, E.P. | **E.A.**, E.P. | **E.A.**, A.C. | E.P. | E.P., **E.A.** |
| Data curation | **E.A.** | **E.A.** | **E.A.** | E.P., **E.A.** | A.R. |
| Manuscript writing | **E.A.** | **E.A.** | **E.A.** | E.P. | A.R. |
| Revision | E.P., L.S., A.C. | E.P., L.S., A.C. | E.P., A.C., L.S. | L.S., M.M. | **E.A.**, E.P. |

Authors: Elena Andriollo (E.A.), Elena Pisani (E.P.), Laura Secco (L.S.), Alberto Caimo (A.C.), Alessandra Rigo (A.R.), Mauro Masiero (M.M.).

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## Chapter 2: Article 1

***Collaborations in Environmental Initiatives for an Effective "Adaptive Governance" of Social–Ecological Systems: What Existing Literature Suggests.***

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**Abstract**

Moving from the scientific literature on the evaluation of environmental projects and programs, this study identifies how and under which conditions collaborations in environmentally sustainable projects are considered effective for the adaptive governance of SES. The method adopted is a systematic literature review based on the quantitative and qualitative analysis of 56 articles selected through specific queries on the SCOPUS database and published from 2004 to 2020. Results of the quantitative analysis identify conditions able to evaluate collaborations, highlighting the need to adopt a transdisciplinary approach analysing both social and ecological challenges and assessing both social and ecological results. Moreover, they suggest preferring using primary data involving multi-sector and multi-scale actors and enlarging the geographical context to the most vulnerable countries. The results of the qualitative analysis provide specific recommendations for collaborations being effective when related to communication, equity, foresight, and respect, which need to be further strengthened by all actors. Multiplicity in visions and approaches should be seen as a resource able to stimulate creativity in social arrangements and environmental practices, making collaborations in environmental projects instrumental for the effectiveness of adaptive governance of SES.

*Keywords: collaboration; adaptive governance; sustainability transformations; social–ecological systems; evaluation; systematic literature review*

**2.1. Introduction**

Human activities are exerting an increasing impact on the environment at all scales, from local to global, endangering the conditions of ecosystems [1,2,3,4,5,6,7,8,9,10,11]. Emergencies that global society is fighting nowadays are evidence of this close connection. Specifically, the COVID-19 pandemic has reinforced this awareness within the scientific community [12] and has probably diffused it to a broader public [13], calling for real sustainable development action [14,15]. Nevertheless, at present, sustainable development is still far from being achieved: "The world today is not sustainable, not resilient and not fair for the majority of mankind" [14] (p. 1).

Complexities and uncertainties characterizing both environmental and social challenges limit the implementation of activities able to effectively catalyze sustainable transformations [16]. In particular, the governance of the environment is challenging because many natural resources are shared among multiple competing actors, provoking conflicts. That is why collaboration is proposed as a promising approach able to address such issues [17]. However, collaboration improves the governance of natural resources if it is effective [18]. Otherwise, collaboration could be seen as a sort of panacea solution that can have no value or even make counterproductive effects [19,20]. To overcome this limitation, at present, the existing literature reveals an urgent need to provide additional knowledge concerning the effectiveness of collaborations both in terms of evaluation approaches [18,21,22,23] and conditions able to foster them [24]. Hence, this study identifies how and under which conditions collaborations are considered instrumental for an effective "adaptive governance" in terms of sustainable transformations in Social–Ecological Systems (SES). The study analyses collaborative relations among different actors involved in environmental programs and projects as analyzed in the scientific literature on environmental evaluation. Specifically, this study aims to provide additional knowledge for (i) improving evaluations of collaborations in future and (ii) providing guidelines for actors to foster effective collaborations. Identifying and classifying findings emerging from evaluations of real experiences allows an understanding of why some collaborations are effective while others fail or collapse [18,25].

The analysis of project and program evaluations, which have been scrutinized through peer-review scientific articles, is at the core of this study. This is motivated by the awareness that evaluations are instrumental to increase the effectiveness of environmental actions, adjusting them to new needs emerging over time through the stimulation of the learning-by-doing process, which identifies previous failures and successes and highlights current needs [26,27]. Specifically, evaluation, and more specifically, self-evaluation, could enhance the performance of future initiatives—through an individual and collective practice of reflection on the process undertaken during the action implementation—if its results pave the way to changing community routines and individual and collective practices and behaviors [28]. Its findings, indeed, can help policymakers to reform or re-design policy instruments but also be helpful for practitioners and, generally, all stakeholders to identify the most relevant and critical aspects for promoting and making valuable and successful their entrepreneurial and social initiatives in the environmental realm [29]. In this perspective, the role of the evaluation is further strengthened if the initiatives can have a clear transformative impact and become utilized and available to the entire society by proposing evidence-based examples on transition practices for sustainable transformations [16].

Effective sustainable transformations are fostered by the capacity of all actors composing society to respond to change through adaptation [30]. This can be achieved through an ongoing individual and collective adjustment aiming at revising environmental activities [31,32]. Accordingly, adaptive governance has been defined as the set of interactions between actors, networks, organizations, and institutions that aims to facilitate transformations to achieve the desired state for SES [32,33]. The SES concept [34] highlights that nature and society coevolve through a reciprocal adaptation process based on interdependencies [8,35,36,37]. In particular, it clarifies that society—intended as people, communities, economies, and cultures [38]—is part of the biosphere and it is entirely dependent on nature [8]. In this paper, we focus on the societal component, and therefore on collaborations amongst humans and their organizations, while exploring in detail the ecological component and networks remains out of the scope.

We focus on collaborations among different types of social actors because sustainability transformations are usually multi-actor and multi-level processes [39] that are characterized by differences in interests, perspectives, needs, knowledge, and resources among stakeholders, leading to possible conflicts, *e.g.,* [40,41,42]. The scientific literature agrees in considering collaborative relationships the most suitable means

to support sustainability transformations [21,43,44,45,46,47]. The literature reports examples of projects which are characterized by good performances in term of effectiveness due to collaboration between different types of stakeholders, such as in biodiversity conservation projects [42], land use planning [48], and protected areas management projects [49]. Collaboration can be seen as "*a set of organizational and interpersonal relationships shaped by the nature of the problems being addressed, the predispositions and capabilities of key actors, and the characteristics of the places in which the problems occur*" [43] (p. 85). Collaborative relationships are characterized by strong interactions between all types of actors involved in the process and by trust and honesty [50]. When they are characterized by accountability and transparency, they contribute to building knowledge, solving conflicts, developing trust or trustworthiness among actors, and connecting different types of actors and sectors that previously worked in isolation to identify common solutions [20,41,51,52]. Collaboration concretely happens through the creation of partnerships. Partnerships arise when different actors share their resources in order to achieve a common goal. Accordingly, creating collaborative partnerships composed of multiple actors is considered an essential tool to face uncertainties and complexities characterizing environmental challenges [53].

The needs, ideas, and actions that emerge from collaborative relationships trigger the coevolving process between society and nature by establishing new social arrangements [33], intended as new roles and interactions of actors [54]. Hence, evaluations of new collaborative interactions emerged from adaptive governance initiatives, and when scrutinized through scientific articles, could identify aspects able to improve their effectiveness and encourage sustainability transformations with a consequent improvement in the quality of SES.

The paper is organized into five sections. After this introduction, the theoretical framework is presented in Section 2, then the materials and methods are specified in Section 3. The quantitative and qualitative results are described in Section 4 and further discussed in Section 5 with concluding remarks in Section 6.

### 2.2 Theoretical Framework

#### 2.2.1 On Key Basic Concepts

This article bases its foundations on the theoretical concepts of sustainable transformations and adaptive governance.

Sustainable transformations refer to changes in social and environmental interactions and feedback in all dimensions of SES by considering resilience and adaptation [30,55]. Transformations are recognized as deliberative actions activated intentionally by actors to realize a significant change (*i.e.*, *radical and non-linear social changes able to cross thresholds into new development trajectories*— [55,56]) to achieve adaptation in SES [57]. Transformations can be different in focus and can be distinguished between ecological (*e.g.*, changes of landscape, ecosystem services, and assemblages of species) and social (*e.g.*, new values, norms, institutions, changes in governance arrangements and everyday practices), with a continuous interplay between these two sets of transformations, which depends on each other [58]. Focusing mainly on social transformations, the assumption at the basis of this study is that changes in social values, rules, and knowledge may impact decisions of individuals and organizations, fostering transformative adaptations based on shared solutions and learning by improving SES quality [31].

Adaptive governance integrates the concepts of transformations, SES, and governance [33]. The governance concept refers as the set of rules, structures, processes, and traditions that determine how people make decisions, share power, exercise responsibilities, and ensure accountability [32,59]. Adaptive governance of SES is, indeed, characterized by participation, experimentation, and collective learning of the different stakeholders involved in diverse phases of collaborative activities, such as the identification, formulation, implementation, and evaluation of environmental policies, programs, or initiatives [35]. Adaptive governance reaches its effectiveness if it is fit-for-purpose, that is, when "(i) its structure enables multiple actors to purposely guide, control, manage or steer societies through network structures that fit with their social and ecological context, (ii) its processes fit with both the network structures in which they take place and the purposes for which they are being used" [19] (p. 76). Consequently, adaptive governance should "(i) provide information (science and local knowledge); (ii) deal with conflict; (iii) induce rule compliance; (iv) provide infrastructure for capacity building; and (v) be prepared for change" [33] (p. 4).

### 2.2.2 On Collaborations

Analyzing how and in which conditions collaborations contribute to the achievement of effectiveness in adaptive governance processes requires focusing on the behaviours, decisions, and activities at the individual and collective levels which determine the effects on the biosphere [8]. Following the adaptive governance concept, the literature on sustainability transformations recognizes the critical role played by individuals and

their interactions in social transformations, meaning "*a set of recognizable activities and attitudes used by an actor to address the recurring situation*" [60] (p. 49). The role appears because of interactions between different social groups and implies expected behaviors, rights, and duties [61]. Accordingly, actors are not passive rule-followers, but they can be active agents in systemic changes, *i.e*., changes in the institutional structure such as thinking, everyday habits, management practices, and resource flows [30]. Actors can exert power and influence the magnitude and effectiveness of transformations through their agency [30,60]. Specifically, [62] identifies four actor categories involved in sustainability transformations: the State, market actors, community, and the third sector (*e.g*., labor unions, NGOs, and science). Different features typify them in the following axes: (i) informal–formal, (ii) profit–non-profit, and (iii) public–private. The State is formal, public, and not-for-profit; the market is formal, private, and for-profit; the community is informal, private, and not-for-profit; and the Third Sector is conceptualized as an intermediary form between the three axes [37], allowing the inclusion of different organizational forms such as social entrepreneurs, social enterprises, and cooperative organizations.

Collaborative interactions between these different typologies of actors create new hybrid forms of governance and evidence the change of the conventional role attributed to a specific actor needed to compensate for limitations of other social agents [60,63], encouraging creativity and, consequently, the development of experimentations through the identification of new ideas, innovative organizational models, new social and environmental practices, novel arrangements, and agreements that potentially could contribute to the achievement of sustainability [30,64]. Moreover, interacting actors define and guide governance processes necessarily impacting (positively or negatively) on nature because they are related transversally with natural components of SES through their decisions and activities [8,22,65]. Such interactions between society and nature constitute SES [8] and are shown in Figure 2.1.

An SES is constituted by interdependent social and ecological systems whose peculiarities are due to their specific context (grey down arrows). If the ecological system can be conceptualized as an interdependent system of organisms or biological units [66] (the green nodes connected through ties in Figure 1), the actors that constitute the social system (the red nodes connected through social relations) could be defined as individuals or organizations intended to generate changes through activities that have environmental impacts [67]. The two systems, *i.e.,* social and ecological, are connected to each other through social and

ecological interactions occurring at multiple levels of adaptive governance [68] where individuals and organizations exert a pressure on the ecological components of the SES and, vice versa, the induced changes on the environment influence actions (the orange arrows). These interactions influence both the flows among resources composing the ecological system (the green lines) and the relations within the social system (the red lines).

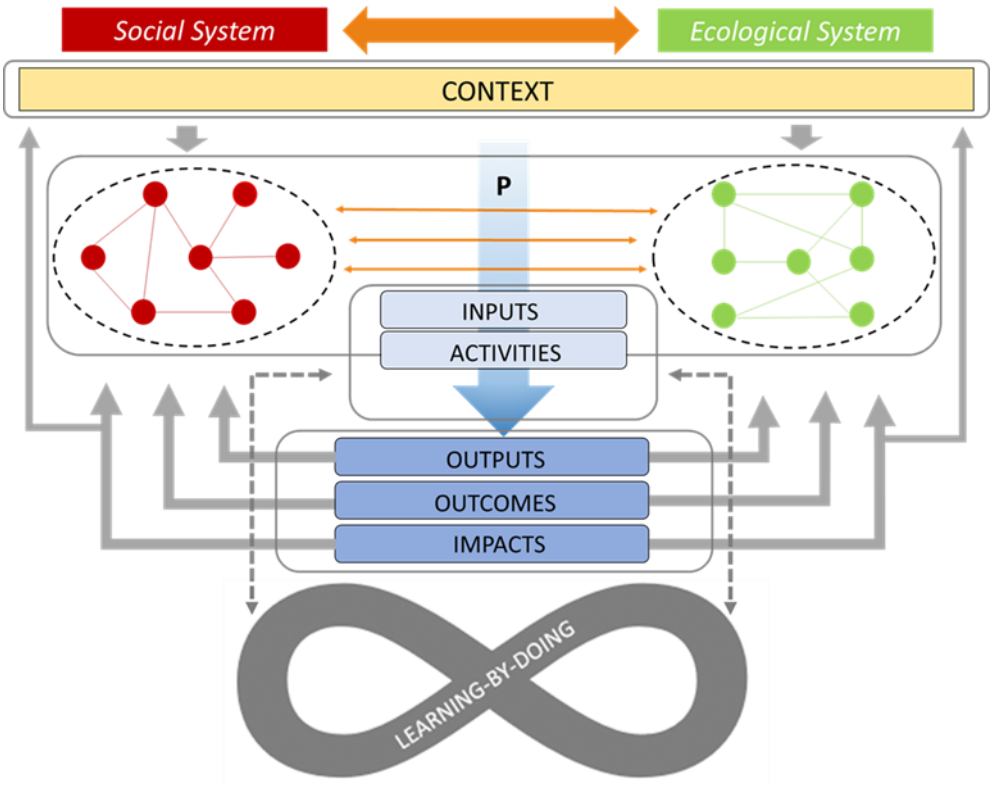


*Figure 2.1. Result chain of adaptive governance activities in SES.*

Effective collaborations in the adaptive governance of SES require that actors guide, control, manage, and steer environmental resources by considering both components, social and ecological. The literature recognizes that by increasing the social connectivity in SES, collaborative activities can improve effective management of the ecological component through the creation of flexible connections among stakeholders formalized in partnerships [20,69]. Connections require sharing of material and non-material resources, facilitating trust-building relations needed to resolve conflicts [17]. Connections can sustain adaptation and trigger sustainability transformations [8,30]. By identifying, formulating and implementing environmental project activities (P), actors can concretize environmental collaborations based on adaptive governance that are able to synergically consider both the social and the ecological systems (blue arrow), fostering

governance activities that could be more fit-for-purpose [19] in producing outputs, outcomes, and impacts ([70] defines outputs as the tangible results made by activities that are relevant for the achievement of outcomes. Outcomes are defined as likely or achieved short-term or medium-term effects. Impacts are defined as positive or negative long-term effects produced by activities) (Figure 2.1) [71,72]. The results of projects could negatively or positively affect the context where they act and both the social and the ecological systems (grey arrows). Moreover, the ongoing learning-by-doing process fostered by evaluations allows identifying improvements in governance activities through an adaptive cycle as shown by dashed grey arrows (Figure 2.1) [30].

**2.3 Materials and Methods**

To understand how and under which conditions collaborations could contribute to effective adaptive governance of SES, we perform a systematic literature review through both a quantitative and qualitative analysis based on reliable and high-quality evaluations reported in the scientific literature [73]. The systematic review is performed to collect and synthesize pieces of evidence emerging from scientific articles focused on the results of the evaluations of environmental activities and extrapolate knowledge on collaborations in adaptive governance of SES [74]. We opted for a systematic review because it allows summarize existing and fragmented knowledge discussed in multiple scientific articles in order to handle the research questions in a sounder way [75]. Specifically, we want to reorganize the scientific knowledge that emerged from experiences already analyzed and evaluated by the scientific community, focusing on evaluating and fostering collaboration in adaptive governance. Steps constituting the literature review process are reported in Figure 2.2.

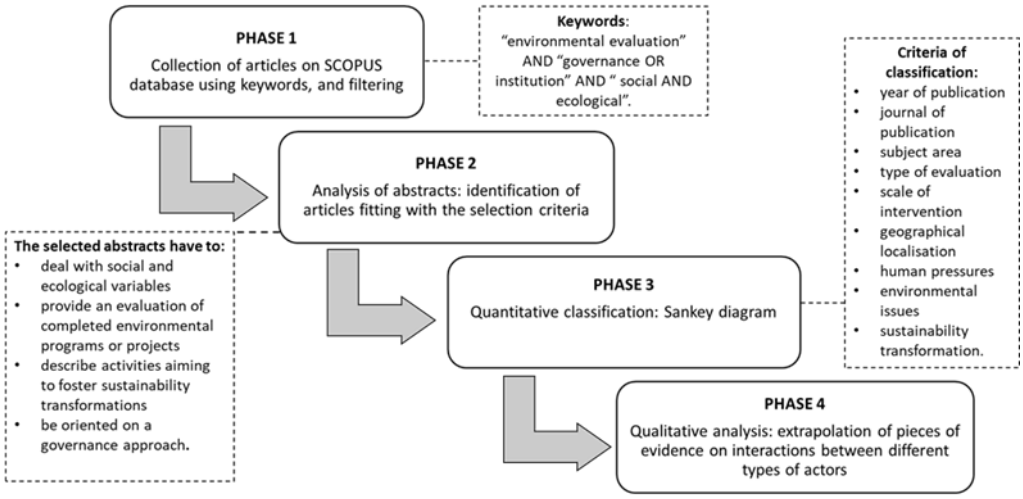


*Figure 2.2. Schematization of the sequence of steps constituting the literature review.*

### 2.3.1 Identification and Extraction of Scientific Papers

For the extraction of scientific articles, we choose the SCOPUS database, whose peculiarities guarantee high quality and reliability. SCOPUS provides the most extensive availability of high-quality journals [76] and articles from around the world, especially on environmental science, and the possibility to have easy access to abstracts for most papers compared to other academic research databases such as Web of Science [77,78,79]. SCOPUS assures the extraction of reliable data through the analysis of scientific articles subjected to peer review process, compared to other databases characterized by a more extensive coverage such as Google Scholar, whose citations derive from multiple sources, which also includes preprints. [80,81]. Accordingly, SCOPUS can be considered the largest curated abstract and citations database, characterized by a selection process on its contents that contribute to preserving the integrity of science. The reliability of such a database is already demonstrated by using SCOPUS for multiple evaluations, such as national assessments, government science policy evaluations, and university rankings [82]. Additionally, SCOPUS better support the implementation of systematic reviews based on key words search than other databases, especially new databases such as Dimensions or Microsoft Academic [83].

To identify articles, we used the following key words combination (string search): "*environmental evaluation*" AND "*governance* OR *institution*" AND "*social* AND *ecological*", in order to gather a collection of scientific articles treating environmental evaluations of programs or projects aiming at fostering sustainability transformations in both the social and the ecological dimensions of SES, with a focus on governance

arrangements. Then, we identified the papers that fit the purpose of the research by reading abstracts using a specific set of selection criteria of the abstracts, as proposed by [84]. The selected abstracts have to: (i) deal with social and ecological variables, (ii) provide an evaluation of completed environmental programs or projects, (iii) describe activities aiming to foster sustainability transformations, (iv) be oriented to a governance approach.

The reduced numerosity of papers allows us to analyze them deeply by reading the whole text and valorizing every statement. By reading their texts, we classify articles and identify evidence related to collaborations through codes reported in MS Excel files and then elaborated through quantitative and qualitative analyses (*e.g.,* [85]).

**2.3.2 Quantitative Analysis of Relevant Data**

The extraction of relevant data for the quantitative analysis, *i.e*., the third step of systematic literature review, was done through a Sankey diagram. The Sankey diagram is a visual tool able to define a flow from one set of values to another, highlighting their relationships. Flows and quantities are visualized from the size of lines connecting a value to another one, evidencing the magnitude of relationships. Accordingly, the wider the lines are, the larger the quantity of the flow is [86]. Here, the flow visualized by the Sankey diagram represents the coexistence in the same article of multiple attributes used for its classification, which define its peculiarities. Every article is classified through the identification of levels pertaining to six different scales. Thus, we transform qualitative information to quantitative data (*i.e.,* number of articles in a certain level, and number of relationships between levels of two consecutive scales) in order to better identify what levels are most addressed by evaluations and what are the most recurrent relationships among levels of different scales.

We first identify the year of publication of articles, in which journals the articles are published, and in which scientific areas articles are included according to the subject areas specified by the journals. After that, we classify articles based on the following scales detailed into different levels: (i) type of evaluations, *i.e.,* Assessment based on indicators or indices, Pure qualitative evaluations, and Integrated evaluations [87]; (ii) scale of intervention of projects or programs evaluated, *i.e*., Local, Sub-national, National, International, Global [68]; (iii) geographical localization, *i.e.,* Africa, America, Asia, Europe, Oceania

(https://unstats.un.org/unsd/methodology/m49/, accessed on 1 June 2021); (iv) human pressures on environmental resources, *i.e*., Agriculture, Forestry, Fishing and hunting, Tourism, Industry, Transport, Urban areas, Waste, Energy, and Climate change [88]; (v) environmental issues, *i.e.,* Biodiversity, Freshwater, Land and soil, Ocean and coasts, and Air [88]; (vi) sustainability transformations addressed, *i.e.,* Sustainable food, land, water and oceans, Health, well-being and demography, Sustainable cities and communities, Energy decarbonization and sustainable industry, Digital revolution for sustainable development, Education, gender, and inequality [36].

### 2.3.3 Qualitative Analysis of Relevant Data

The fourth step is the extrapolation of pieces of evidence (statements as reported in the text of the article) on interactions between different types of actors as categorized by [62], *e.g.,* in the case of the article proposed by [41], State actors are the federal and provincial fisheries departments, market actors are local fishers and aquaculture operators, community actors are local and aboriginal communities, and third sector actors are research institutions and multiple NGOs. All statements related to pieces of evidence on interactions are collected in an Excel spreadsheet file, clarifying: (i) what are the categories of the actors involved in the relationship (*i.e.,* the State, market, community, and the third sector); (ii) if and how the relationship has been effective or not in dealing with the environmental challenge in the analyzed SES (*e.g.,* resolution of conflicts around multiple uses of marine space through the development of a new institution [41]).

Finally, a qualitative content analysis reviews and summarizes the heterogeneous knowledge by grouping the statements (narrative text) with an equal or similar meaning into homogeneous categories aggregated around broad concepts emerging from our interpretation of contents reported in articles.

## 2.4 Results

### 2.4.1 Selected Papers

The selection of articles on the SCOPUS database identifies 194 articles, which are consequently filtered, considering only articles and reviews written in the English language (147). After analysing abstracts, 56 papers (listed in Appendix A) fit with all the four criteria identified in Section 3 to address the research purposes and are used.

### 2.4.2 Quantitative Results

The analysis reveals that selected articles are relatively recent, and the oldest is published in 2004. Figure 2.3 shows that evaluations of environmental governance activities fitting with the research criteria are mostly published in the last decade, *i.e.,* after 2010, with a maximum value in 2016 (nine articles published). Then, the number of articles reaches stability with five to six papers published every year.

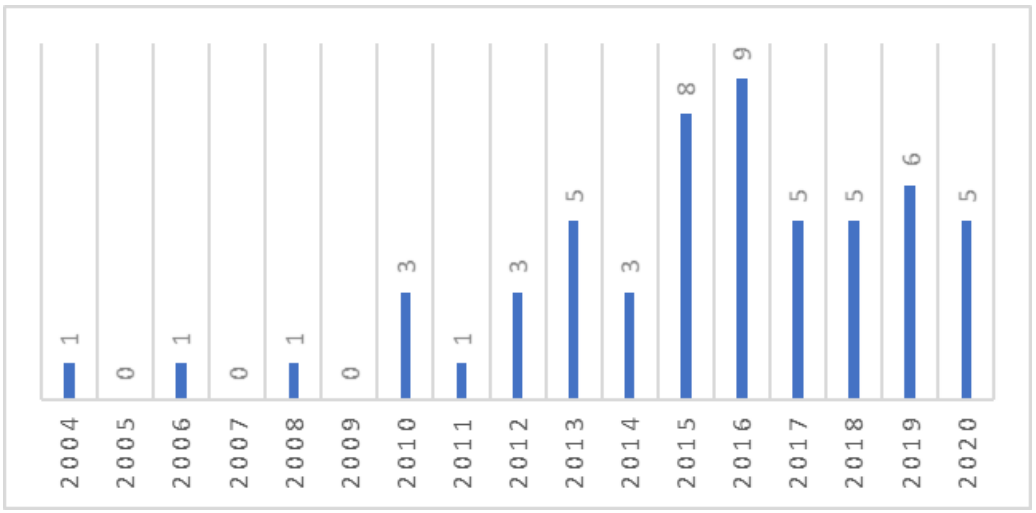


*Figure 2.3 Numerosity of articles selected by the systematic literature review per year.*

As reported in Appendix B, the selected articles are published in several journals and subject areas, which mainly belong to the Environmental Sciences (54 articles), followed by Social Sciences (22), and Agricultural and Biological Sciences (16). In addition, the classification identifies other subject areas such as Medicine (7), Economics, econometrics and finance (9), and Energy (4), evidencing the transdisciplinary nature of the topic we are exploring.

The Sankey diagram (Figure 2.4) shows relationships between all the scales and levels used for classification purposes. Each paper can be part of multiple classification scales and levels at the same time. Thus, the total numbers specified for each scale and for each level do not align with the total number of 56 articles.

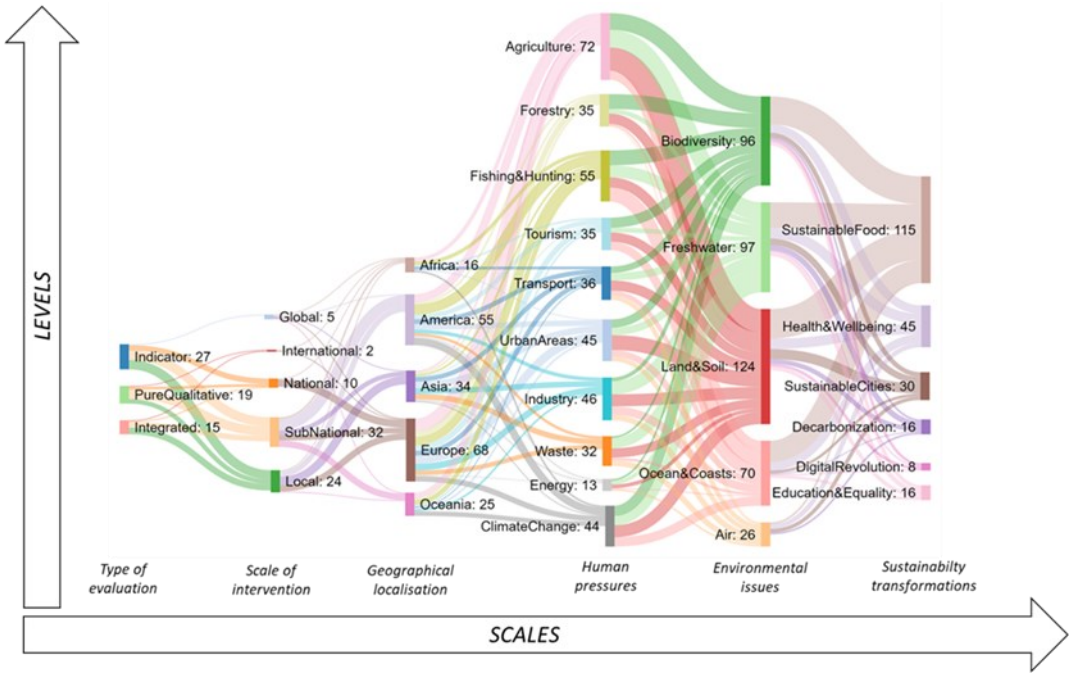


*Figure 2.4. Classification of articles by Sankey diagram.*

Starting from the scale "Type of evaluations" as reported in the articles, we observe that evaluations using indices or indicators create 27 relationships, evaluations using pure qualitative methods create 19 relationships, and evaluations using a combination of participative approaches and multicriteria assessments create 15 relationships.

Moving to the "Scale of intervention", it is possible to observe that indicator assessments and pure qualitative methods are used transversally for all the levels from local to global, while integrated assessments are mostly used in evaluations at a minor scale, mostly sub-national and local. The 77% of relationships constituting the Sankey diagram focuses on program or project activities implemented at the sub-national and local levels. A minor number of relationships focuses on a national (14%) or international scale (3%), and only one article refers to a global scale (it creates five relationships because it relates with all continents).

Focusing on the "Geographical localization", it is possible to observe that studies are mostly localized in developed countries. In fact, the geographical area with the highest number of activities analyzed is Europe with 68 relationships (34%). The review selects articles that analyze initiatives placed in all continents: Africa (8%), America (28%), Asia (17%), and Oceania (13%). However, it reveals that the poorest areas remain understudied (*e.g.,* Sub-Saharan Africa or the Middle East).

Observing the “Human pressures” scale, it emerges that Agriculture is the most recurrent pressure in terms of relationships (17%), followed by Fishing and Hunting (13%), Industry (11%), Urban Areas (11%), and Climate Change (11%). Forestry (8%), Tourism (8%), Waste Production (8%), and Transport (9%) are less investigated, and Energy receives a little attention (3%).

Moving to “Environmental issues”, the analysis reveals that Land and Soil counts 124 relationships (30%), while Freshwater and Biodiversity total 97 and 96 relationships, respectively (23% for both). Then, Ocean and Coasts attest 70 relations (17%), followed by Air with 26 relations (6%).

More specifically, if Agriculture, Climate Change, and Fishing and Hunting seem to be transversal pressures impacting all of the most addressed environmental issues, from the Sankey diagram it emerges that Forestry and Tourism mainly impact on Biodiversity and Land and Soil, while Industry and Urban Areas mainly impact on Freshwater and Land and Soil. Transport, Waste, and Energy production are mainly related to Land and Soil and Freshwater, but it is also possible to appreciate a relevant number of relationships targeting the environmental issue of Air.

Finally, focusing on the framework proposed by [36] on sustainability transformation, the classification highlights that most of the initiatives relate to the achievement of sustainability in food production, land use, water use, and oceans (115), followed by initiatives aimed to improve community health and well-being (45) and by initiatives which aim at achieving sustainability in cities and communities (30). A minor number of relationships are related to energy decarbonization and sustainable industry and education, gender, and inequality (16 both), then followed by digital revolution for sustainable development (8).

### 2.4.3 Qualitative Results

The selected articles offer several examples of evaluations of interventions dealing with the improvement of adaptive governance of SES through the identification of novel solutions. Examples of evaluations undertaken are: (i) *ex-ante* evaluations of the impact caused by specific types of land use in protected areas [89]; (ii) participative evaluations aimed at creating awareness on environmental issues [90]; and (iii) the identification of best practices for resilient environmental management [24]. The following paragraphs summarize the recommendations on how and under which conditions collaborations contribute to the effective adaptive governance of SES as highlighted and suggested by evaluation results. In order to facilitate

the comprehension, the qualitative results are grouped into four categories having a common conceptual significance: (i) Communication, (ii) Equity, (iii) Foresight, and (iv) Respect. These categories and their main components emerged from the analysis of the articles are summarized in Figure 2.5.

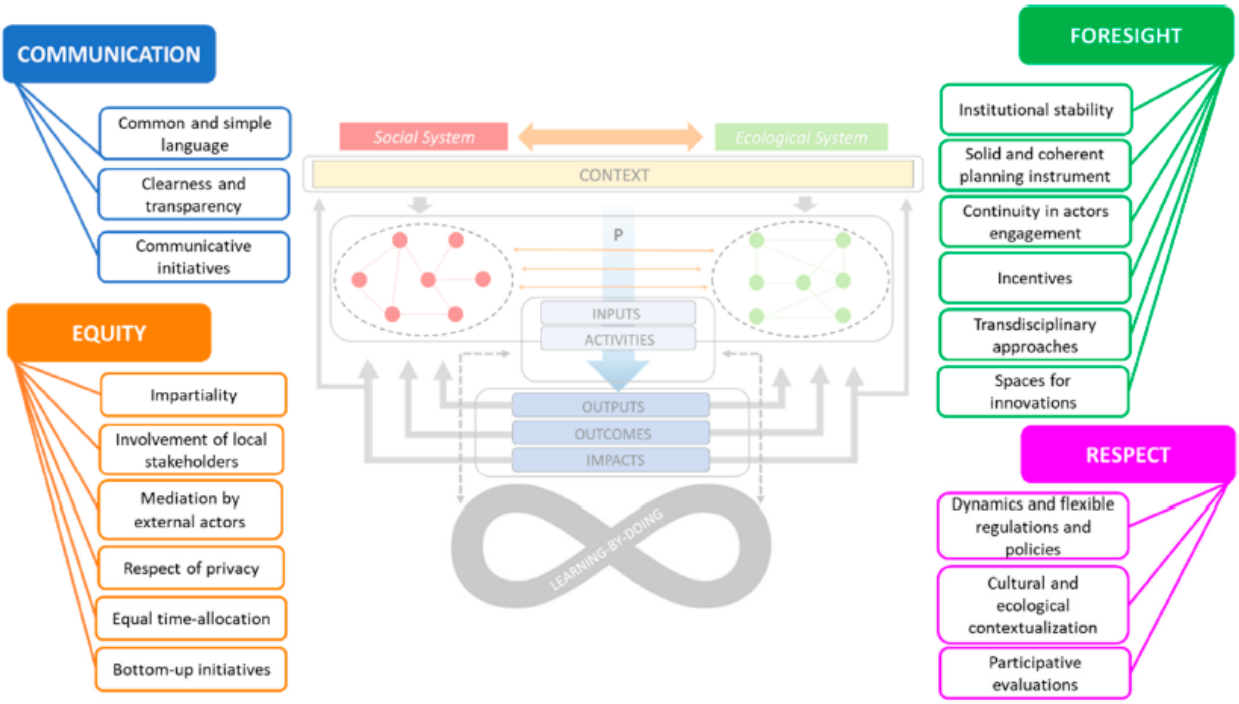


*Figure 2.5. Categories and components fostering effective collaborations as highlighted by articles selected by the systematic review.*

#### 2.4.3.1 Communication

Most of the selected articles highlights the importance of clear communication among multiple stakeholders, where individuals, groups, and organizations can express their values and perceptions. Developing a common language, specifically if it is informal and not technical, helps to avoid misunderstandings among actors [41,89,91,92]. Instrumental for effective collaborations is the use of visual tools—more user-friendly and for all types of people (also for illiterate people)—in communicating environmental issues or in participative evaluation processes [24,49]. Therefore, evaluations recommend clearness and transparency in communicating the contents of regulations, recommendations, directives, and so on from public bodies to all the other types of stakeholders, especially on the content of policy objectives both general and specific [48,93,94,95,96,97]. Scientific communication is fundamental for community education. Third sector actors

as proposed by [62]—especially researchers, but also NGOs and generally all public actors—to play a fundamental role in the transmission of scientific knowledge to all other actors [96,98,99,100]. To be effective, the content of scientific communication has to be clear and make use of tools able to be applied by non-experts [42,101,102], especially by policymakers who normally steer, guide, control, and manage natural resources. Moreover, public actors are invited to increase the number of communicative initiatives and tools aimed to make the community aware of environmental challenges and to propose everyday practices able to foster sustainable behaviors through the awareness that sustainable actions are more convenient for their well-being [92,103,104].

#### 2.4.3.2 Equity

The integration of different typologies of actors, especially underprivileged stakeholders, and the respect of equity also within participative initiatives are essential for establishing relationships based on trust and respect [24,26,41,42,48,89,92,95,98,99,105,106,107,108]. In participative processes, there is always the risk that interests of the elites prevail or that some groups of relevant actors are excluded in the decision-making processes [24,48,91,96,109]. Therefore, moderators or facilitators have the fundamental role in assuring equity through an objective and impartial management of trade-offs on interests and needs among actors [26,99,106]. The need for equity explains why collective initiatives are often sustained by external groups of experts, mostly NGOs and universities [100,110] who involve local stakeholders through, *e.g.,* citizen-science tools, trips, workshops, and practical exercises of participative multicriteria assessments [24,26,90,93,94,100,111,112]. In order to guarantee equity in participative decision-making processes, facilitators and moderators have to assure the respect of privacy and allocate time allowing all actors to equally express their opinions and values [42,89]. In addition, public and third sector actors are requested to coordinate and stimulate people to think and act for the good of all communities and to recognize valuable allies in local stakeholders [23,92,97,99,108,109,113,114]. Additionally, public authorities are required to devolve some power and autonomy to bottom-up initiatives that emerge from adaptive governance processes [41,90,99,100,115]. Accordingly, all actors are invited to share material and non-material resources by considering a self-help perspective [96,98] in order to overcome limits that could preclude sustainability transformations, (*e.g.,* the creation of ecotourism infrastructures in Amazon villages as suggested by [24]).

Specifically, private actors are invited to avoid influencing scientific activities and research themes through the allocation of private funds on specific research themes that do not positively impact on the society [93].

#### 2.4.3.3 Foresight

Sustainability transformations require interventions producing effects in the long term, which contrast with individual needs focused on short-term outputs. Following this view, [116] underlines that several environmental projects are funded on a short-term period. To address this weakness, public bodies are requested to maintain the attention and the support on environmental initiatives in the long term by developing solid and coherent planning instruments. Institutional stability seems able to reduce the "stakeholder apathy" [42] and to assure continuity in environmental adaptive governance initiatives [41,42,49,91,96,117,118,119]. Considering public actors, [99] highlights the need to also support collaboration between partners after the end of the project through the creation of a stable network of actors sharing common objectives and working together for a more extended period. This could be fostered by programs having a long- or medium-term vision that can promote the resilience of ecosystems [99,102,120,121,122,123,124]. Experiences highlight the strategic nature of proposing tools to motivate private actors to be involved in sustainability transformations. Accordingly, private actors are more likely to act when it is easy and convenient to do the right thing [26]. Sustainability transformations need to be proposed as means able to increase their well-being through, for example, the introduction of incentives [26,97,106,125]. The incentive has not to be only monetary (*e.g.,* payments, subsidiaries) but also of a different nature (*e.g*., new job opportunities) [48,91,117]. To sustain innovations that foster sustainability transformations, donors are invited to sustain transdisciplinary research [94,96]. On the other side, third sector and State actors are invited to create common spaces for boosting innovations [42,126]. Equally, private actors, and in particular market actors, must be encouraged to sustain scientific research, especially for the development of innovative eco-friendly technologies [127]. Moreover, they are invited to trust in science and accept changes in their everyday lives, even if it is difficult to see the short-term advantages [128].

#### 2.4.3.4 Respect

Relevant and suitable sustainability transformations need dynamic and flexible regulations and policies that take into consideration social and ecological characteristics and the scale where interventions take place in order to address specific emerging needs that continuously evolve among time and space [26,95,97,118,129,130,131]. This is why the State and third sector actors are requested to comprehend real problems dealt by local stakeholders (both community and market) [92,100,110]. In addition, public interventions need to be culturally contextualized, and they have to respect traditions (*e.g.,* everyday practices and taboos) of communities where they are placed, especially in non-Western countries, in order to build trust and legitimation [24,41,91,98,99,108,111,128,132]. To do so, the literature invites the promotion of participative evaluations processes [108,133]. Accordingly, evaluations need to provide specific information on both the environmental and social contexts and to include indicators related to the quality of life of locals, especially of indigenous communities, which very often appear as the most marginalized groups [93,94,96,105,122,129,134,135,136].

## 2.5 Discussion

The evaluations presented in the 56 articles highlight: (i) how effective governance of SES is difficult to achieve due to complexities and uncertainties which characterize environmental and social challenges presented in the different contexts analyzed and (ii) a specific and context-based environmental issue is typically characterized by multiple social and institutional stakeholders interconnected through different ties with a set of interrelated environmental resources, as already pointed out by *e.g.,* [30,32].

Through the results of the quantitative and qualitative analyses, we want to provide and help to (i) improve evaluations in future and (ii) provide guidelines to actors to foster effective collaborations. The following discussion firstly presents specific indications on how to assess the effectiveness of collaborations, and secondly, examines how actors could foster them.

### 2.5.1 How to Assess the Effectiveness of Collaborations

*1. All typologies of evaluations should adopt a transdisciplinary approach when dealing with the assessment of collaborations for the adaptive governance of SES.*

The analysis of evaluations reported in the articles demonstrate that articles use basically a transdisciplinary approach. This is corroborated by results showing that the majority of articles selected by the review (42 out 56) are published in journals belonging to multiple subject areas. In addition, the analysis identifies two main approaches used to assess adaptive governance initiatives: (i) articles dealing only with social variables (18) and (ii) transdisciplinary articles dealing with both social and ecological variables (38). The heterogeneous variables used in the 56 analyzed articles attest that transdisciplinary research is instrumental to provide a transversal knowledge fitting all dimensions of sustainability [137], as reported by, *e.g.*, [101,111]. Nevertheless, transdisciplinary approaches involve difficulties in their operationalization, specifically related to the diversity of interests, values, and perceptions of actors involved in adaptative governance initiatives [138].

*2. Evaluations normally centered on secondary data should also use participative techniques for primary data collection. This will allow to reach a better understanding of real situations of evaluated contexts, which is a necessary pre-condition for effective collaborations.*

The scientific literature recognizes the central importance of using participative approaches in all the phases of the project cycle, *e.g.,* [48,49,114], in order to determine a real impact in the target context. Nevertheless, moving to the classification of evaluations reported in articles, we observe that articles using social and environmental indicators or indices limit the use of participative approaches in evaluations, *e.g.,* [115,127]. Pure qualitative articles can be subdivided into two categories: on one side, some articles use participative approaches in projects, *e.g.,* [90,100], and on the other side, some articles focus on analyses of policy, *e.g.,* [93,119]. Conversely, articles based on integrated assessments reveal that the involvement of the community by using participatory approaches plays a determinant role in (i) the identification of needs or environmental challenges tacking local communities, *e.g.,* [24,89,109]; (ii) the implementation of project activities, *e.g.,* [49,105,108]; (iii) the evaluation of undertaken actions, the successful reaching of their objectives, and consequently, the impacts of the initiatives, *e.g.,* [42]. Experiences demonstrate that knowledge sharing among local actors helps identify the specific needs of local communities and the interlinks among environmental and social problems, which are not immediately visible to the external managers, who typically adopt a sectorial problem-solving approach. In addition, ex-ante participative evaluations allow discussing local problems permitting people to take consciousness of the importance of the environmental

challenge and identify context-based solutions that local community supports [52,89]. Results support the need to enlarge the use of participative approaches in all types of evaluations, specifically in evaluations based on indicators and indices that normally rely on secondary data to better represent real situations of evaluated contexts.

*3. Evaluations of adaptive governance initiatives of SES should involve actors from multiple spatial scales.*

In terms of scale of intervention, our systematic literature review shows that evaluations are mainly focused on sub-national or local levels. Conversely, it evidences a low number of evaluations implemented at national, international, and global scales. Evaluations of sub-national and local interventions are characterized by a high frequency of activities based on participative approaches also implemented through multicriteria assessments, *e.g.,* [48,99]. The local scale of intervention probably fosters the generation of effective collaborations in SES [139,140]. Consequently, evaluations based on sub-national and local scales would be more prone to assess these collaborations. Nevertheless, the literature highlights the need to avoid inward-looking approaches because the majority of SES does not limit to the narrow boundaries of the SES analyzed but is open and susceptible to external changes [48,141]. Consequently, [142] propose to involve actors from multiple scales in participative approaches, combining together different interests to compensate for this weakness. Equally, multiple evaluations selected by the review adopt the same approach, involving stakeholders from different spatial scales, *e.g.,* [99,107]. A quantitative analysis of relationships constituting networks through the Social Network Analysis (SNA) could be helpful in the assessment of connectivity between actors of adaptive governance initiatives, *e.g*., [69,107,143].

*4. Evaluations on collaborations for adaptive governance of SES should enlarge the context of analysis to countries that, at present, are most vulnerable to climate change and natural resources depletion.*

The geographical analysis of articles reveals a high concentration of evaluations in Europe, America, and Australia. Sub-Saharan Africa and the Middle East, which are more vulnerable to climate change effects and natural resources depletion, do not attest to a scientific discussion on the research topic. Studies placed in poor areas mainly deal with activities related to Western countries activities such as wildlife tourism, *e.g.,* [91,107,109]. Thus, the geographical analysis of articles denotes a Western-centric vision in scientific research related to the evaluation of sustainability issues and environmental challenges. This evidence is

confirmed by multiple other studies related to sustainability analysis, *e.g.*, higher education for sustainable development in [144] and resilience thinking in [145].

*5. Evaluations of adaptive governance should focus on both environmental and social challenges to identify collaborations able to foster synergies in SES.*

The focus on human pressures evaluated by this study highlights that environmental actions reported in the articles have repercussions in addressing crucial social challenges that humanity, at present, has to deal with. Sustainability practices in food supply chain and in actions undertaken in urban areas are the most recurrent challenges in the selected articles. Agriculture and Fishing and Hunting, followed by Urban Areas and Industry, are human pressures with the highest number of relationships within the Sankey diagram. This could be explained because one of the most critical challenges that humanity must deal with in the future years will be the exponential increase of the global population and the consequent increasing demand for food to assure food security for all people [88,146] and the migration of people from rural to urban areas [147]. Accordingly, most of the adaptive activities reported in articles selected by the review focus on (i) food production in rural and urban areas*, e.g.*, [106,112]; (ii) fishing activities, *e.g.*, [41,105]; and (iii) the evaluation of sustainable practices in urban areas*, e.g.*, [103,121]. Synergies between social and ecological challenges are supported in multiple international agreements and policies, *e.g.*, Agenda 2030 and Sustainable Development Goals (SDGs) or the Farm to Fork EU Strategy [4,148]. Accordingly, it is not surprising that the number of articles selected by this study is highest in 2015 and 2016, when SDGs emerge in the international policies. Hence, evaluations need to focus on both environmental and social outputs that emerge from collaborations, as already exemplified by, *e.g.,* [24,94].

*6. In order to assess the effectiveness of collaborations within environmental projects and programs, evaluations should focus on synergies and trade-offs among multiple environmental challenges determined by human actions at the same time. Therefore, they should be multi-sectorial.*

Environmental issues dealt by articles are mostly related to the use of (i) Land and Soil and (ii) Freshwater, and the conservation of (i) Biodiversity and (ii) Oceans and Coasts. Little attention is devoted to the Air. Evaluations analyzed by our literature review demonstrate the necessity to consider multiple environmental issues simultaneously, such as the interdependencies between land use and biodiversity as pointed out by,

*e.g.,* [52,107]. Accordingly, the scientific literature highlights the need to consider synergies and trade-offs among multiple environmental issues generated by implementing human activities [36]. For example, in the case of agricultural activities negatively impacting on the environment, the evaluation should consider the interactions among food supply, water use, and biodiversity loss [149,150]. The generation of effective collaborations, able to cope with multiple negative effects determined by human actions, can be stimulated by the inclusion of actors of multiple sectors, as evidenced in the scientific literature*, e.g*., by [151,152]. Our review provides examples of various cross-sector collaborations, such as the participative evaluations that involve fishers and tourist operators, *e.g.,* [42,99,109]. Nevertheless, despite the recognition that multi-sectoriality is fundamental for an effective environmental governance, the experiences highlight difficulties in its concretization due to different needs, visions of the world, problems to be addressed, terminology*, etc*., in multiple sectors [40,41,42]. From this background emerges the relevance and the need of trade-offs in identifying common and shared strategies to be implemented by collaborations of multiple and different actors, which, at present, are scarcely examined by the scientific literature [15].

*7. Evaluations of the governance of SES should consider the role of effective collaborations to promote transformations towards improved community well-being.*

Articles selected by the literature review are mainly focused on transformations related to the sustainable use of natural resources such as land and oceans, followed by transformations aimed at fostering human well-being and the sustainability of urban areas. Evaluations should focus on interventions not only in terms of assessment of the quality of ecosystems, but also as opportunities to foster community well-being through the catalyzation of multiple facts such as inclusiveness, equality, trust, education of the community, and the respect of rights and cultures, which can lead to the achievement of a thriving global society [153,154]. Accordingly, selected articles provide multiple examples of environmental evaluations which consider environmental interventions as means able to foster community well-being. For example, [24,49] demonstrate how effective management requires the involvement of indigenous communities and the respect of their cultures and lifestyles. Furthermore, [106] shows that the environmental projects placed in post-industrial cities not only impact the environmental quality, but they also accelerate environmental justice and social equity. However, at present, top-down and centralized approaches neglecting the fundamental role of local community and of peculiarities of contexts and cultures are still the most used in

the governance of environmental resources [93]. Evaluations on collaborative efforts addressing specific environmental challenges through a bottom-up approach could be useful in the identification of new solutions able to improve both natural ecosystems and human well-being [17].

### 2.5.2 How to Foster Effective Collaborations

*1. A clear communication fosters community support to environmental activities, and consequently, it increases the possibility to foster effective collaborations through community awareness on environmental challenges.*

The qualitative analysis of the final considerations reported in the analyzed articles shows that a clear communication can empower locals, help in resolving conflicts, and help communities define good practices for contributing to sustainability transformations. In addition, a transparent information on activities and outputs can favor the reliability of actions undertaken by the promoters of adaptive governance initiatives, facilitating community trust [91,136]. Clear communication fosters community awareness on environmental challenges and its support on environmental activities, *e.g.,* [90,103], especially in contexts of poverty and marginalization, where people have little chances to be empowered through traditional channels, *e.g.,* schooling [24,121]. For example, [106] observes that a clear communication in relation to urban community gardening has the possibility to include the most marginal groups in community activities to empower them and foster their pro-environmental behavior, and, consequently, their support of the objectives of the initiative.

*2. Equity fosters the emergence of a conscious and shared environmental responsibility through the identification of common strategies by multiple stakeholders that support effective collaborations.*

Evaluations analyzed by the qualitative analysis highlight that equity in participative processes stimulates the emergence of a conscious and shared environmental responsibility among all stakeholders who have different rights and duties related to the environmental issue to be tackled [41]. Therefore, messy problems, such as environmental challenges, require the active participation and contribution of all people affected by them and with a specific and fundamental knowledge to be valorized and integrated to find solutions to cope with uncertainty and complexity. Thus, real dialogue, grassroots democracy and social movements represent fundamental aspects to be sustained and valorized through governance processes [155]. This is why, adaptive

governance initiatives characterized by equity are more prone to generate meaningful dialogue between different actors, and, consequently, the identification of strategies in agreement with all parts involved, which considerate needs and opportunities for all actors, including the less powerful, *e.g.,* [24,89,103,105,106,108,109,114,128,155].

*3. Foresight in the governance of SES fosters a constant process of adaptation, supporting effective collaborations in the long run.*

The qualitative analysis reveals that foresight is necessary for sustaining the transformative process that essentially constitutes adaptive governance as described by the adaptive cycle [30]. Accordingly, foresight is crucial in fostering changes in natural resource management through the introduction or development of new tools or novel approaches that could lead to the implementation of innovations [49,52,90,110,123,127,132,155]. Forward-looking initiatives can assure continuity in the transformative process also after the end of projects through the creation of networks of actors who continue to collaborate in order to stimulate additional improvements of the governance of SES (*e.g.,* through the creation of new governance arrangements such as alliances and spin-offs, as reported by [90]). The continuity of collaborations in the long-term period through, *e.g*., regular periodical meetings [42], is, in turn, instrumental in avoiding the stakeholder apathy characterized by the declining of exchange of knowledge and the engagement of stakeholders and leadership [42,96].

*4. Respect of social and ecological contexts leads to the design and implementation of relevant activities, building trust and legitimation, and, consequently, fostering effective collaborations.*

The initiatives described in the analyzed articles show that the respect of both ecological and social contexts is a prerequisite for implementing effective initiatives and collaborations. Context-based approaches lead to the design and implementation of relevant initiatives that consider both (i) the ecological conditions evolving in time and space and (ii) local cultures and lifestyles. From the articles selected by the literature review emerges the fundamental role of policies able to adapt to every specific area and social need, which, consequently, can support new governance arrangements generated by adaptive governance initiatives [90,93,96,100]. Relevant projects can build trust and legitimacy, helping with the generation of effective collaborations between the local community and external actors proposing initiatives*, e.g.,* [24,49,99,155].

### 2.5.3 Managerial Implications

Clear communication, equity, foresight, and respect also need to be considered from a managerial point of view. In particular, if interventions concern SES, they are requested to focus on both the social and the ecological peculiarities from their starting phases. This is highlighted in multiple policy documents (*e.g.,* Agenda 2030 [156]; Paris Agreements [157]; The European Green Deal [158]) and program regulations (*e.g.,* LIFE Programme [159]; Interreg Europe [160]). In particular, the most general indication that emerged from this study is to valorize the fundamental role of community involvement from the very beginning of every project. Local actors, whom project managers often consider as passive beneficiaries of project results [161], need to be involved and converted into active stakeholders through the devolution of responsibilities and autonomy in actions implementation [162]. Accordingly, building a shared environmental responsibility among jurisdictional levels is functional for increasing the effectiveness of activities [155,163]. In the following paragraph, we provide indications on how to increase people engagement and, thus, sustain collaborations in the different phases constituting the project cycle.

*(i) Identification, formulation*: project designers are requested to clearly identify stakeholders and their potential role in the phases of identification and formulation through the stakeholder analysis (*e.g*., influence and matrix) and through the SWOT analysis [48,155,164]. In addition, to guarantee equity, the identification of possible coalitions constitutes a necessary step in order to prevent that elites prevail in decision-making processes [89,155]. Project designers should involve local communities from the very beginning by respecting the values and culture that could be better understood through the use of both informal conversations and well-designed questionnaires and surveys [100] or multicriteria assessments to be performed with the active participation of representatives of the local communities [48,52,89]. Instrumental, since the identification of the project, is the schedule of different meetings among stakeholders aimed to identify problems and resolve possible conflicts and identify possible trade-offs in the decision-making process [41].

*(ii) Implementation, monitoring:* effective collaborations among multiple stakeholders could be supported and stimulated through the involvement of stakeholders in regular meetings in order to avoid stakeholder apathy [42] and the promotion of the creation of new bottom-up experiences such as spin-offs and alliances [90]. Trips, festivals, and special events are fundamental for communicating project objectives and results, stimulating a pro-environmental behavioral change of community that, consequently, is more prone to

support project interventions [90]. Citizen science is instrumental for the involvement of people but also for the monitoring of activities [93,155].

*(iii) Evaluation:* evaluations of projects need to consider the environmental results derived by projects implementation and social outcomes derived from them. As highlighted by [94] is fundamental to assessing all dimensions of sustainability (*i.e.,* environmental, social, and economic) through developing suitable indicators. Additionally, evaluations need to be participative and include all types of stakeholders, especially local actors, as reported by [49], using tools that better fit with people cultures and peculiarities. Conversely, evaluations and results diffusion need to be clearly communicated to everybody through, *e.g.*, public events designed not only for technicians but also for non-experts [24]. Instrumental in communicating project results is the identification and spreading of best practices [106].

**2.6 Conclusions**

Our review of evaluations makes evident that transdisciplinary, multi-scale, and multi-sector approaches should be applied to assess the effectiveness of collaborations in adaptive governance of SES. Moreover, it shows that participative approaches are instrumental in understanding the context where initiatives are placed and demonstrate that environmental actions implemented through effective collaborations should promote social well-being. Four broad concepts can resume the conditions able to catalyze effective collaborations in the governance of SES. They include clear communication, equity, foresight, and respect. They are seen as characteristics able to incentive the inclusion of stakeholders, their trust, and consequently, their support in the definition and implementation of relevant initiatives, and to assure the continuing of the transformative process that constitutes the adaptive governance of SES.

From our analysis, it emerges that the effectiveness of adaptive governance initiatives is essentially based on processes established through the involvement of multiple actors and the consequent emergence of social networks. Future studies and evaluations of environmental projects and programs could better analyze the connectivity between actors, for example, increasing the application and use of Social Network Analysis.

Despite the abundance of recommendations that emerge from the analysis of articles related to interactions among different actors, evaluations mainly focus on the role of public actors (*i.e.,* State and third sector), with little attention on the contribution of private actors (market and community). To address this gap, future

studies could focus on the side of private actors and develop user-friendly tools to foster sustainability in everyday behaviors.

Moreover, this analysis highlights the need to highlight and valorize the most marginal voices embedded in adaptive governance. Evaluations about adaptive governance of SES located in developing countries could be opportunities for the creation of new knowledge through the sharing of both scientific and traditional/indigenous knowledge, which could propose new effective solutions and approaches useful for sustainability transformations to be also implemented in different contexts.

The study presents some limitations which are related to the selection of articles through a set of limited keywords, the analysis of articles written only in English and the use of the SCOPUS database. We are aware that other articles dealing with effectiveness of adaptive governance of SES, and providing innovative perspectives useful for scientific process could be excluded from the analysis due to the selection process or their marginalization because of their limited statistical representation. Nevertheless, we believe that this literature review provides a useful initial overview of the current knowledge and possible improvements in evaluation of collaborations within adaptive governance of social–ecological systems and their global to local challenges.

**Author Contributions**

Conceptualization, E.A., E.P., and L.S.; methodology, E.A. and E.P.; data curation, E.A.; writing—original draft preparation, E.A.; writing—review and editing, E.A., E.P., and L.S.; supervision, E.P., L.S., and A.C. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest**

The authors declare no conflict of interest.

**Appendix A: List of articles selected for the systematic review.**


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**Appendix B: Table 2.A1. Journals where selected articles are published and their subject areas.**

| Journals | n. of articles | Subject areas | | |
|---|---|---|---|---|
| **Ambio** | 1 | Environmental Science | Medicine | Social Sciences |
| **Carpathian Journal of Earth and Environmental Sciences** | 1 | Earth and Planetary Sciences | Environmental Science | |
| **Ecological Economics** | 3 | Economics, Econometrics and Finance | Environmental Science | |
| **Ecological Indicators** | 2 | Agricultural and Biological Sciences | Decision Sciences | Environmental Science |
| **Ecology and Society** | 10 | Environmental Science | | |
| **Ekoloji** | 1 | Agricultural and Biological Sciences | Environmental Science | |
| **Environment and Planning C: Government and Policy** | 1 | Environmental Science | Social Sciences | |
| **Environment, Development and Sustainability** | 1 | Economics, Econometrics and Finance | Environmental Science | Social Sciences |
| **Environmental Education Research** | 1 | Social Sciences | | |
| **Environmental Management** | 2 | Environmental Science | Medicine | |

| | | | | | |
|---|---|---|---|---|---|
| **Environmental Monitoring and Assessment** | 1 | Environmental Science | Medicine | | |
| **Environmental Policy and Governance** | 1 | Environmental Science | Social Sciences | | |
| **Environmental Science and Policy** | 2 | Environmental Science | Social Sciences | | |
| **Erdkunde** | 1 | Earth and Planetary Sciences | Environmental Science | Social Sciences | |
| **Fish and Fisheries** | 2 | Agricultural and Biological Sciences | Earth and Planetary Sciences | Environmental Science | |
| **Fisheries Oceanography** | 1 | Agricultural and Biological Sciences | Earth and Planetary Sciences | | |
| **Forest Policy and Economics** | 1 | Agricultural and Biological Sciences | Economic, Econometrics and Finance | Environmental Science | Social Sciences |
| **Frontiers in Marine Science** | 1 | Agricultural and Biological Sciences | Earth and Planetary Sciences | Engineering | Environmental Science |
| **Global Environmental Change** | 1 | Environmental Science | Social Sciences | | |
| **Integrated Environmental Assessment and Management** | 1 | Environmental Science | Social Sciences | Medicine | |
| **International Journal of Agricultural Sustainability** | 1 | Agricultural and Biological Sciences | Economics, Econometrics and Finance | | |
| **International Journal of Environmental Research and Public Health** | 1 | Environmental Science | Medicine | | |
| **Journal of Environmental Management** | 4 | Environmental Science | Medicine | | |
| **Journal of Environmental Planning and Management** | 1 | Chemical Engineering | Environmental Science | Social Sciences | |
| **Journal of Environmental Studies and Sciences** | 1 | Environmental Science | Social Sciences | | |
| **Journal of Sustainable Forestry** | 1 | Agricultural and Biological Sciences | Energy | Environmental Science | Social Sciences |
| **Marine Policy** | 2 | Agricultural and Biological Sciences | Economic, Econometrics and Finance | Environmental Science | Social Sciences |
| **Ocean and Coastal Management** | 1 | Agricultural and Biological Sciences | Earth and Planetary Sciences | Environmental Science | |
| **Regional Environmental Change** | 1 | Environmental Science | | | |
| **Regional Studies** | 1 | Environmental Science | Social Sciences | | |
| **Resources Policy** | 1 | Economics, Econometrics and Finance | Environmental Science | Social Sciences | |
| **Science of the Total Environment** | 2 | Environmental Science | | | |
| **Shengtai Xuebao/ Acta Ecologica Sinica** | 1 | Agricultural and Biological Sciences | Environmental Science | | |
| **Sustainability (Switzerland)** | 3 | Energy | Environmental Science | Social Sciences | |
| **Water Policy** | 1 | Environmental Science | Social Sciences | | |

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## Chapter 3: Paper 2

***Collaborative environmental governance for nature and biodiversity in the EU-funded LIFE-NAT projects (2014-2020): evidence emerging in Italian protected areas.***

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**Highlights**

- LIFE Programme promotes collaborative governance for biodiversity in protected areas.
- LIFE-NAT projects partnerships are constituted mostly by public actors.
- Protected areas authorities are fundamental in catalyzing multi-actor collaboration.
- Local bodies participation leads to collaboration between people where projects act.
- Involving more local bodies requires investments in capacity building and networking.
- Collaborative governance for nature occurs where wildlife is economically recognized.

**Abstract**

Protected areas are considered one of the most important tools to address biodiversity issues, ensuring the conservation and restoration of species and habitats and providing essential ecosystem services for social wellbeing. The European Union recognizes their fundamental role through the Natura 2000 network, as well

as its Biodiversity Strategy 2030, and dedicated a relevant part of the LIFE Programme, the EU's funding instrument for the environment and climate action, for its extension and management. Assuming collaboration instrumental for the catalyzation of effectiveness in environmental governance, through a network analysis approach, this research aims to verify if the LIFE Programme can sustain collaborations to manage protected areas through a multi-actor and multi-level governance approach. We take as a case study all LIFE-NAT Italian projects co-funded in the 2014-2020 programming period. The analysis focuses on 45 projects realized through collaborative partnerships, by 211 beneficiaries. Results show that protected areas authorities and managers are the actors most prone to lead collaborative efforts for nature conservation and biodiversity support among different public and private actors through LIFE-NAT projects, ensuring multi-actor governance and multi-level relationships between national and regional bodies. Nevertheless, this analysis highlights the need to increase the participation of private and local bodies, which often directly benefit from ecosystem services provided by nature, to guarantee the maintenance of effective collaborative governance after the end of LIFE-NAT projects.

*Keywords: LIFE Programme, collaborative governance, protected areas, networking, Social Network Analysis.*

**3.1 Introduction**

This study aims to verify if the EU co-funded LIFE Programme, one of the most important financial tools established at a European level for nature conservation and restoration, is effectively able to stimulate and support a collaborative governance for biodiversity preservation and measure the extent in which it has supported the collaborative governance through a network approach. Biodiversity loss can be considered one of the most critical environmental challenges that society nowadays has to face (WWF, 2020; UNEP, 2019; Cumming, 2016). Biodiversity, in fact, is essential in assuring human wellbeing through the provision of ecosystem services to society (IPBES, 2019; Costanza *et al.,* 2017; TEEB, 2008). Specifically, biodiversity is a source of food and essential nutrients, medicines and medicinal compounds, fuel, energy, livelihoods, cultural and spiritual enrichment, it contributes to the mitigation of climate change and natural disasters, and pests or diseases, and it makes available clean water and air (EEA, 2020; Romanelli *et al*., 2015). Additionally, pieces of evidence demonstrate that biodiversity promotes health and wellbeing, *e.g*., decreased depression and stress, increased happiness, and creativity, reduced mental fatigue, reduced headaches and mortality from circulatory and respiratory diseases, reduction in spread of infectious diseases

including some zoonotic diseases (Marselle *et al.,* 2019; Mavoa *et al*., 2019; Sandifer *et al*., 2015). Additionally, Covid-19 pandemic effects increasingly reinforce the recognition of such positive role of biodiversity (Lawler *et al*., 2021; Mc Neely, 2021; Terraube and Fernández-Llamazares, 2020). Nevertheless, at present, the quality of biodiversity is affected and endangered by human activities, specifically by changes in land and sea use, species overexploitation, invasive species and diseases, pollution, and climate change (IPBES, 2019; Tilman *et al*., 2017), showing that nature and society are strictly interdependent (WWF, 2020; Folke *et al.,* 2016; Martín-López and Montes, 2015). Environmental and social challenges need to be dealt synergically to guarantee both healthy ecosystems and thriving societies (Geijzendorffer *et al.,* 2017).

Accordingly, in the last decades, multiple international agreements have been proposed and implemented to address synergically social and environmental challenges related to biodiversity conservation, *e.g*., the Convention of Biological Diversity, Aichi Targets, Agenda 2030, and the UN Decade for ecosystem restoration (Fischer *et al*., 2021; Burgass *et al.,* 2020; Folke *et al.,* 2016). In the European context, the European Union (EU), through the Green Deal, is currently introducing multiple ambitious environmental and climate strategies and commitments aiming at restoring and protecting European ecosystems without compromising social needs and economic growth (Krämer, 2020) and allowing to make Europe the first climate neutral continent by 2050 (EC, 2019). In particular, the EU 2030 Biodiversity Strategy, in response to biodiversity loss challenges, highlights the crucial importance to reconnect society with nature, investing resources for nature conservation and restoration, benefitting both people, the planet, and the climate (EC, 2020). Specifically, the strategy recognizes the importance of protected areas and the necessity to extend their size, allowing them to preserve threatened natural species (EC, 2020). Protected areas, indeed, as one of the most important tools for biodiversity conservation and restoration, represent a reserve of functional ecosystems able to conserve ecosystem services that are currently providing and restore degraded ecosystems in the future, assuring a regional social-ecological resilience (Cumming *et al*., 2016). Therefore, EU Commission aims "*to do more and better for nature and build a truly coherent Trans-European Nature Network*", establishing protected areas for at least 30% of the land and 30% of the sea in Europe enlarging the Natura 2000 network (EC, 2020 p.4). However, establishing new protected areas and appropriately managing those already existing have a lot of challenging implications in terms of actors' engagement and effectiveness of governance approaches, as we will show in the following sub-section 3.1.1.

### 3.1.1 Collaborative environmental governance of protected areas

Despite the recognition of the fundamental role of protected areas for the purposes of EU biodiversity conservation and restoration policies, the scientific literature reveals multiple criticisms related to the management of protected areas in the European territory, *e.g*., (i) conservation policies applied in protected areas are very often centralized and standardized, they are not adaptive and able to consider peculiarities of the place where they act (Alfarè *et al*., 2020; Miles *et al*., 2020; Staniscia *et al*., 2019; Nita *et al*., 2018), (ii) local stakeholders very often are not involved in the decision-making process (Miles *et al*., 2020; Staniscia *et al*., 2019; Hossu *et al*. ,2017; Sarvašová *et al*. ,2013), (iii) management plans are often too vague and abstract, without details and information on how interventions will be implemented for achieving their objectives (Hossu *et al*., 2017), (iv) the institutional framework is very complex and immediate interventions are challenging to implement (Alfarè *et al*., 2020). Consequently, conflicts between public authorities and other stakeholders often arise in the establishment and management of protected areas localized in Europe, *e.g*., in Natura 2000 sites (Pecurul-Botines *et al*., 2019; Manolache *et al.*, 2018; Etxano *et al*., 2015; Sarvašová *et al*., 2013), in national parks (Arpin and Cosson, 2021; Staniscia *et al*., 2019) and marine protected areas (Miles *et al*., 2020). Tensions arise because protected areas in Europe are established in territories already occupied and used by the local communities who feel threatened by new limits and obligations that could impede traditional economic activities (Romano *et al*., 2021; Staniscia *et al.,* 2019). In addition, economic resources allocated by national policies for the conservation, maintenance and expansion of protected areas result insufficient compared to their needs, highlighting how economic factors can be considered one of major obstacles of nature conservation development in EU countries (Malovrh *et al*., 2019). To overcome local mistrust and economic limitations, protected areas need to be proposed as tools able to foster local sustainable development through the support and promotion of alternative models of economic development while preserving the environment and valorizing biodiversity peculiarities in a sustainable way (Romano *et al*., 2021; Staniscia *et al*., 2019; Saviano *et al.,* 2018a). Generally, conservation activities aimed to reach sustainable development are fostered by collective actions of multiple typologies of actors involved in different activities and acting at different jurisdictional levels, that together identify common strategies able to address both social, environmental, and economic needs (Di Franco *et al.*, 2020; Bodin *et al*., 2016; Folke *et al*., 2016; Lockwood, 2010). Interdependencies between multiple sectors and jurisdictional levels involved in protected areas management require a shared environmental responsibility among all actors

exerting a role in their management (Manolache *et al*., 2018; Lockwood, 2010). The importance of the inclusion of every actor in the co-design and management of conservation efforts implies the recognition that exclusive top-down management of protected areas, traditionally used in the past, appears inappropriate for the achievement of effective environmental governance (*e.g.,* Lockwood, 2010). It needs to be complemented or replaced by bottom-up approaches, which support and valorize collaboration among different actors operating in the same place and sharing same objectives (Armitage *et al*., 2012; Black *et al*., 2011, Lockwood, 2010). Accordingly, Bodin (2017) recognizes the tendency to associate the concepts of environmental governance and collaborative governance through the introduction of the new term "*collaborative environmental governance*" referring to "*collaborative approaches to environmental management in a general and inclusive sense*" (p.1).

An effective collaborative environmental governance of protected areas requires a multi-actor and multi-level approach (Alexander *et al*., 2017, Lockwood, 2010), often crossing administrative borders. Specifically, if the typologies of actors involved in collective environmental activities could be related to the three main groups defined by Lemos and Agrawall (2006) (*e.g*., State, market and community), then the concept of jurisdictional levels refers to the units of analysis localized at different positions on the jurisdictional scale (*i.e*., a clearly bounded and organized political or administrative unit), and here distinguished as: international, national, regional and local (Cash *et al.,* 2006). Ecosystems are complex entities disregarded from man-made jurisdictional and political demarcations, requiring governance approaches that support intersections of actions across different jurisdictional scales implemented by multiple typologies of actors (Bodin, 2017). Multi-actor governance – characterized by horizontal connections between different typologies of actors operating at the same jurisdictional level – can foster trust and collaboration, contributes to social learning, and spreads innovations. In addition, it can facilitate coordination between intersecting departments, agencies, and sectors to implement synergic interventions (Alexander *et al*., 2017; Hossu *et al*., 2017; Sarvašová *et al*., 2013). Multi-level governance can vertically connect actors across different administrative levels, facilitating feedback loops between local administrators and higher-level decision-makers by providing new sources for ideas, information, and other resources (Alexander *et al.,* 2017; Folke *et al.,* 2016; Berkes *et al.,* 2010). The need for collaboration between different and multi-level actors fits with the network governance concept (*e.g*., Pisani *et al*., 2020; Grönholm, 2018; Manolache *et al.*, 2018; Ernstson *et al*., 2010). Accordingly, Bulkeley (2005) states that decision-making in environmental governance is

"*created, constructed, regulated and contested between, across and among scales, and through hybrid governing arrangements which operate in network terms*" (p.874). In protected area management, an effective network governance is stimulated by central actors when they can create and consolidate a stable network of actors interacting through collaborative relationships within a well-defined normative framework (Manolache *et al*., 2018). Therefore, protected areas managers result central actors in protected areas management because they are often the main public authority in charge for managing the area (*e.g*., Lai, 2020), consequently, they have the role of mediators between specific local needs and global environmental objectives, *e.g*., fostering new local activities through the support of higher-scale initiatives (Romano *et al*., 2021; Manolache *et al*., 2018; Thomas and Middleton, 2003). Accordingly, several examples evidence the need to include the local community, especially the privates, to guarantee transparency and a clear communication between managers and stakeholders (Di Franco *et al*., 2020; Giglio *et al*., 2019) and to define clear guidelines and objectives in management plans (Giglio *et al*., 2019; Hossu *et al.*, 2017; Lockwood, 2010). Specific public policy interventions and allocation of appropriate resources, such as those established by means of the EU LIFE Program described in the following sub-section 1.2, might help to support the establishment and effective functioning of such a kind of collaborative governance approaches.

### 3.1.2 The EU LIFE Programme

At present, the EU offers several financial opportunities through project funding to sustain the collaborative governance for nature and biodiversity, such as those provided by the LIFE Programme (https://ec.europa.eu/environment/nature/biodiversity/financing_en.htm). This can be considered one of the most important European tools for environmental purposes that can catalyze a collaborative governance through the implementation of environmental and climate projects. "*Since 1992, LIFE programmes have played an essential role for better solidarity and responsibility sharing in preserving the common good of the Union's environment and climate*" (EC, 2013 preamble 4). Through the LIFE Regulation 2021/783, the EU Parliament and Council recognize the necessity to reduce the biodiversity loss process and the degradation of ecosystems through the "*support for the development, implementation, enforcement and assessment of relevant Union legislation and policy*" (EC, 2013 preamble 16). In particular, the LIFE Programme is proposed as a tool contributing to "*halting and reversing biodiversity loss, including by supporting the implementation and management of the Natura 2000 network and tackling the degradation of ecosystems, either through*

*direct interventions or by supporting the integration of those objectives in other policies*" (EC, 2013 preamble 3). Its structure and requirements (*e.g*. co-funding mechanisms), indeed, facilitate and provide opportunities for the concretization of collaborations between diverse actors pertaining to different levels of governance by creating partnerships, which are often transnational. Due to the transnational feature of the LIFE Programme, the project partnerships can be of course composed by national, European, and international actors. In the last programming period (2014-2020), the Programme allocates a large number of resources for the implementation of activities aimed at the priority of sustaining nature conservation and restoration, *e.g*., 55% of the Environment subprogram budget is totally dedicated to this goal, especially through LIFE Nature (LIFE-NAT) projects (EC, 2013 art.9). In the current programming period (2021-2027), the Programme confirms its focus on nature conservation and restoration, dedicating one of the four LIFE sub-programmes to Nature and Biodiversity (EC, 2021). This sub-programme aims to (i) improve the management of protected areas, (ii) reduce the spreading of alien species, (iii) valorize habitat and species conservation and restoration, and (iv) develop a coherent Natura 2000 network in all European territories to achieve the EU 2030 Biodiversity Strategy (https://cinea.ec.europa.eu/life/nature-and-biodiversity_en). Consequently, analyzing the collaborative governance catalyzed and sustained by the LIFE Programme means analyzing the collaborative governance of the most important source of EU funding dedicated to the management, conservation, and restoration of protected areas (Sánchez-Fernández *et al*., 2017).

### 3.1.3 Social Network Analysis

Relationships between LIFE project beneficiaries are here analyzed through a network approach adopting Social Network Analysis (SNA), the primary method used in this study. SNA is a methodology suitable for analyzing collective actions based on relationships between different actors, like the selected LIFE-NAT projects proposed by beneficiaries constituting the project partnership. Accordingly, Bodin and Crona (2009) demonstrate that SNA can analyze relationships between multiple actors, disentangling complex and hidden relations that determine the success or limitations of activities based on collaboration. Specifically, Bodin (2017) shows that through the structural analysis of networks made by SNA, it is possible to define if the governance network is characterized by cohesiveness, centralization, or compartmentalization, extracting information about governance processes and tendencies affecting collaborations. Additionally, the study of characteristics of nodes intended by SNA as attributes of nodes allows to deepen if relationships are

restricted to a specific set of actors or if they are transversal, and the identification of the most powerful groups in the network (Alexander et al., 2017; Bodin and Crona, 2009). When studying governance, the network analysis of nodes' attributes is helpful to verify the presence of multi-actor and multi-level governance processes through the analysis of vertical and horizontal ties bringing multiple types of actors pertaining to different jurisdictional levels together to collaborate, coordinate activities, and share knowledge as the implementation of LIFE projects requires (Alexander et al., 2017).

### 3.1.4 Objectives and structure of the paper

Applying of a social network approach and taking as case study of reference all the LIFE projects financed through the LIFE-NAT priority area and coordinated by an Italian institution or organization in the last programming period (2014-2020), this study aims to verify if the EU LIFE Programme is an appropriate tool to effectively stimulate and support a collaborative governance for nature conservation and biodiversity preservation, and measure the extent in which it has supported the collaborative governance through a network approach. The guiding research questions are:

Q1. *To what extent and in which way LIFE-NAT projects promote a multi-actor and multi-level governance? How are LIFE projects partnerships consequently structured?*

Q2. *What are the most important actors in the network of beneficiaries involved in selected LIFE-NAT projects? Do central actors have similar characteristics?*

Q3. *How the collaborative governance for nature conservation and biodiversity restoration is effectively concretized in the Italian territory through the implementation of LIFE-NAT projects? Are there any geographical hotspots of effective collaborative governance evidenced by LIFE-NAT projects implementation?*

The article is organized into five sections. After this introduction, Section 2 presents materials and methods. After that, Section 3 presents the results and Section 4 proposes their discussion, and, finally, Section 5 concludes with final remarks.

## 3.2 Materials and Methods

### 3.2.1 Case study area

Even if the study limits its analysis to the Italian national contexts, the analysis could be replicated in all European contexts and all jurisdictional levels (from sub-national to European) because data used for the analysis are available for all the EU areas. This study chooses the Italian context as the case study area. Italy is a European Mediterranean country characterized by high institutional, cultural, social, and environmental complexities that make this case study an important benchmark for further works.

Focusing on a socio-economic perspective, which is not simple to synthetize in few sentences, Italy is characterized by socio-economic disparities between the Northern and the Southern regions and a particularly accentuated urban-rural divide within regions. Additionally, it is possible to identify regional polycentric systems like the Po Valley, Tuscany, and Apulia (Lanfredi et al., 2022).

Focusing on the ecological perspective, the variability of climatic, biogeographical, and geological features makes Italy one of the European countries with the highest rate of biodiversity in Europe, accounting for more than two-thirds of all terrestrial and freshwater habitats valorized by the European environmental policy (Gigante et al., 2018). Italy is characterized by a high richness of landscapes and cultures and an extensive network of protected areas (Romano et al., 2021; Lai, 2020; Saviano et al., 2018b; Sallustio et al., 2017). Additionally, Italy, as one of the countries pertaining to the Mediterranean basin, is one of the EU areas most affected by climate change which impact on the quality of ecosystems through the increasing frequency of extreme events like floods, droughts, storms, and forest fires, the increase of temperatures and the diffusion of invasive species (e.g., Trucchia et al., 2022; Nascimbene et al., 2020; Amendola et al., 2019). Moreover, climate change tendencies and unsustainable landscape transformations put some Italian areas at desertification risk (Coluzzi et al., 2022).

Focusing on the institutional perspective, although limited to biodiversity conservation, heterogeneities in the management of protected areas among the 21 administrative regions and autonomous provinces (Secco et al., 2017), ecological peculiarities and differences in the main goals (landscape peculiarities maintenance vs biodiversity conservation) make Italy a relevant context of investigation for the analysis of a traditional top-down conservation approach based on national and European legislations complemented by bottom-up

initiatives of LIFE-NAT projects implementation (Romano et al., 2021; Lai et al., 2020; Eckerberg et al., 2015; Romano and Zullo, 2015).

Protected areas in Italy cover 21% of land and ca. 2% of sea, quite far from the targets of 30% each set by the EU Biodiversity Strategy. The 52% of Italian protected areas are Natura 2000 sites regulated by the EU legislation (Habitat Directive 92/43/CEE and Bird Directive 79/409/CEE); ca. 11% are protected areas regulated by the national legislation (L. 394/1991). Quite a significant percentage (37%) are protected areas under both the Italian and European regulations (https://biodiversity.europa.eu/countries/italy). The establishment of protected areas in the Italian territory addresses the need to preserve the fragile and complex equilibrium between nature and human activities in territories that are still not degraded. Protection, indeed, is the primary aim of protected areas establishment. However, from the establishment of the national law on protected areas (L. 394/1991), the legislation is approaching a valorization view, considering protected areas as tools to promote sustainable development (Saviano *et al*., 2018b). Specifically, in the Italian context, the peripherical position of territories protected by regulations aiming at conservation of nature implies the necessity to valorize new forms of sustainable development (especially in economic sectors like tourism, sustainable agriculture, and traditional food production) to minimize the abandonment and depopulation characterizing such areas (Romano *et al*., 2021; Saviano *et al*., 2018b). Also, Italy is recognized as one of the European countries which most benefit for European grants co-funded by the LIFE Programme, due to the limited amount of national and regional public fund for nature and climate change and the proactive role of the national contact point (EC, 2017).

### 3.2.2 LIFE Projects, Beneficiaries and Protected Areas analyzed by the study

As mentioned in sub-section 1.2, LIFE projects partnerships can include national, European or international actors. For the purpose of this study, through the LIFE Programme Database functionalities, we select all LIFE-NAT projects having as coordinating beneficiary an Italian actor in the last programming period (2014-2020). At present, information is available for LIFE projects accepted and funded by the European Commission from 2014 to 2019. We focalize on LIFE-NAT projects because the priority area "Nature and Biodiversity" specifically aims to contribute to the development of European policies related to nature conservation, the support of the management of Natura 2000 Network sites and to provide knowledge for the monitoring and assessment of biodiversity within and outside EU territories (EC, 2013). After identifying suitable LIFE

projects, we (i) collect all organizational information related to projects (*e.g.*, name, acronym, period of implementation), (ii) identify the institutional or organizational attributes (*e.g.*, name, country, typology of actor, jurisdictional level, financial budget co-funded by the LIFE programme) related to every actor composing LIFE projects partnerships (both coordinating and associated beneficiaries) and (iii) specify if and where their actions take place in Natura 2000 sites, collecting the code of every Natura 2000 site involved and its GPS localization. Specifically, to verify if LIFE projects stimulate a multi-actor and multi-level environmental governance, we classify every beneficiary involved in LIFE projects partnerships considering its typology and jurisdictional level. We classify the typologies of actors referring to the LIFE Programme database categorization of actors "beneficiary type" which distinguishes development agency, intergovernmental body, local authority, mixt enterprise, national authority, park-reserve authority, professional organization, public enterprise, regional authority, SME – small and medium-sized enterprise, training centre, and university. Furthermore, we classify the jurisdictional level of every partner, referring to Cash *et al.* (2006) specifically considering: international, national, regional, and local levels. Finally, in order to verify the presence of transnational partnerships, we report the nationality of all LIFE beneficiaries.

### 3.2.3 Data extraction and databases creation

Information related to LIFE projects and actors is available on the LIFE Programme website since 1992 (https://webgate.ec.europa.eu/life/publicWebsite/search). The LIFE Programme database allows selecting LIFE projects having specific characteristics (*e.g.*, priority area, in our case study "NAT", *i.e.,* "*Nature and Biodiversity*") through the application of filters. Once identified the relevant LIFE projects, for everyone it is possible to visualize an informative spreadsheet with (i) project description (background, objectives, results), (ii) administrative data (projects code, acronym, start and end time, total budget, EU contribution and project website), (iii) contact details of the coordinating beneficiary, (iv) environmental issues addressed (themes, keywords, target EU legislation, target habitat types, Species, Red List Species, Natura 2000 sites), (v) beneficiaries composing the partnerships (name and nationality), (vi) other information like the link of the project website and additional documents. We add information related to the funding allocation between partners and Natura 2000 sites, consulting the EU Financial Transparency System (https://ec.europa.eu/budget/financial-transparency-system/analysis.html) where are reported all detailed financial information of EU co-financed projects from 2007 to 2020, including the LIFE Programme, and the

Natura 2000 database provided by the European Environment Agency (https://www.eea.europa.eu/data-and-maps/data/natura-12) where descriptive and geographical data for every Natura 2000 site are available. We extracted data, we created a new database with all selected projects and information related to every LIFE-NAT project ("*Projects section*"), every beneficiary composing the projects partnerships ("Beneficiaries section"), and every Natura 2000 site involved in projects ("*Natura 2000 section*"). For every LIFE-NAT project, we report its: (i) code, (ii) name, (iii) Natura 2000 sites involved, (iv) coordinating beneficiary, (v) associate beneficiaries, (vi) year of funding, (vii) total EU contribution. For every beneficiary we report its: (i) name, (ii) typology, (iii) scale of intervention, (iv) nationality, (v) EU co-financing. For each Natura 2000 site we report its: (i) name, (ii) code, (iii) country, (iv) region, (v) type, (vi) area (ha), (vii) GPS coordinates. Information not available in the LIFE Programme database, the EU Financial Transparency Systems and the Natura 2000 database was collected through the consultation of websites of LIFE projects or websites of projects beneficiaries. The projects selection and data extraction have been carried out December 2021.

### 3.2.4 Data analysis methods

SNA is the main methodology used in this study. It is instrumental in addressing our research questions Q1 and Q2. SNA is the study of relations among multiple nodes defined by edges constituting the analyzed network. In particular, SNA analyses the node position in the network that is essential in predicting the performances and behaviours of every node embedded in the network (Borgatti *et al.,* 2013). Accordingly, Bodin and Crona (2009) highlight that SNA can identify central nodes able to lead the information and resource flow in the network. In this study, nodes represent beneficiaries constituting LIFE project partnerships, and their relations (edges) connect the coordinating beneficiary with all associate beneficiaries involved in the same partnership. Undirected relationships characterize nodes because of the assumption that information and resources are equally shared between coordinating and associate partners (Leventon *et al*., 2017). SNA has already revealed its suitability in analyzing collaborative environmental governance. This methodology, indeed, is applied in other studies that analyze the collaborative environmental governance for nature conservation and restoration, such as the analysis of the governance of the Natura 2000 network (Laktić *et al.,* 2020; Manolache *et al*., 2018; Nita *et al*., 2018), marine protected areas (Alexander *et al*., 2017; Markantonatou *et al*., 2016), and parks (Calvet-Mir, 2015; Nuno *et al*., 2014).

Using information reported in the LIFE Programme database, we create two MS Excel spreadsheets, the first with all information related to actors, based on the "*Beneficiaries section*", and the second, based on the "*Project section*", explicates their relationships, indicating what node is the source and the target of every edge in the network. Specifically, in this study, the source of every edge is the coordinating beneficiary of the project, which relates with the associate beneficiaries. Consequently, data have been elaborated by Gephi® software.

The visualization of the project network through a graph and the calculation of SNA statistics contribute to address Q1 and Q2. Specifically, multi-actor and multi-level governance (Q1) are verified by analyzing the homophily in relationships composing the network. Homophily refers to the tendency of actors to relate with actors having similar characteristics compared to others (Di Gregorio *et al*., 2019). To verify homophily in relationships, we calculate the E-I Index (Krackhardt and Stern, 1998) that ranges from -1 to +1. If the E-I index value is negative, there is homophily in relationships, and if it is positive, there is heterophily (*i.e.,* actors tend to relate with others having different characteristics in relationships). We calculate the E-I index considering attributes related to the following scales: (i) typologies of actors and (ii) jurisdictional levels. Having a positive E-I index means the presence of a high diversity among connected actors coming from different sectors and jurisdictional levels (*e.g*., Di Gregorio *et al*., 2019), attesting the presence of heterogeneity in connections which could enhance effectiveness of activities through *e.g*., the exchange of resources and information, the integration of plans, and the up scaling of local initiatives, concretizing a multi-actor and multi-level governance (Bodin, 2017; Guerrero *et al.,* 2014; Bodin and Crona, 2009). Nevertheless, diversity in connections does not mean necessarily more effectiveness in terms of biodiversity protection because heterogeneity could imply longer processes, tensions during the projects, *etc*. (Bodin, 2017; Bodin *et al.,* 2016). Conversely, homophily in collaborative environmental initiatives could reduce their effectiveness because actors connect only with their similar, excluding other relevant actors, provoking conflicts in the management of natural resources, and reducing integration and coordination of multiple environmental activities (Guerrero *et al*., 2014; Newman and Dale, 2007). After calculating the E-I index for both scales, we calculate the density of edges related to every level of the two scales.

SNA statistics of centrality are instrumental in addressing Q2. In particular, we analyze the degree centrality and betweenness centrality of nodes. The degree centrality index measures the number of relationships

established by every node (*i.e.,* the number of edges possessed by every node), the betweenness centrality index measures how often a node is placed in the shortest path between the other two nodes (Borgatti *et al.*, 2013). Bodin and Crona (2009) highlight repercussions on the position of nodes in governance networks. Representing the number of collaborations that a specific organization has: a high value of degree centrality has positive effects on the actor's influence. Actors with high degree centrality can be considered as "*hubs*" of networks, coordinating actions of multiple actors, diffusing and controlling the flow of information and resources to the rest of the network, acting as political entrepreneurs (Schoon *et al*., 2017; Romolini *et al*., 2016). Moreover, an actor having a high betweenness centrality acts as a bridge and gatekeeper between two actors, who cannot relate if they are not connected by the broker, having the possibility to influence the flow of information and resources and, at the same time, providing new and diverse resources to more isolated actors through the bridging ties (Schoon *et al*., 2017; Romolini *et al.,* 2016). Therefore, after calculating centrality measures, we identify central actors and compare each other considering the following features: typologies of actors, jurisdictional level, and amount of EU budget co-funded. The identification of the most central actors will allow to understand what types of actors and what jurisdictional level better foster collaborations through the implementation of LIFE-NAT projects in the Italian context through a multi-actors and multi-level governance, taking also in consideration the amount of EU funds allocated to every beneficiary (*e.g*., Pisani *et al*., 2020).

The analysis of the localization of Natura 2000 sites involved in selected LIFE-NAT projects, helpful in addressing our research question Q3, is performed using GIS technologies. Precisely, using data reported in the "Protected areas" section of the database created for the purposes of this study, through the use of ArcGIS ®, we localize and visualize all Natura 2000 sites where selected LIFE-NAT projects are placed. In addition, we classify Italian regions considering the extension and numerosity of protected areas benefitting from LIFE-NAT implementation compared to the total area and numerosity of protected areas.

### 3.3 Results

#### 3.3.1 Network analysis of partnerships implementing LIFE-NAT projects (research questions Q1, Q2)

Figure 3.1 shows the network of LIFE beneficiaries constituted by the partnerships of the Italian LIFE-NAT projects selected for this study (45 in total). Actors composing the network are 211 and they are related

through the establishment of 241 undirected relationships. In figure 1 actors are characterized: (i) through colors referring to their typology of actor, (ii) through node size referring to their betweenness centrality (*i.e.,* the larger the node, the higher the index value, the higher capacity of creating connections and collaborations with other beneficiaries) and (iii) through their position in levels referring to a jurisdictional level from international to local. Specifically, the jurisdictional level refers to the level at which actors are recognized by the law for public entities. Conversely, private actors are classified considering the jurisdictional level at which they act. We choose this representation due to its functionality in answering Q1 and Q2, which are addressed in sub-sections 3.1.1 and 3.1.2.

The graph (fig.3.1) shows that most of beneficiaries creates a unique central network. Only two partnerships localized at the right side of the graph, are isolated from other actors. Moreover, 39 actors are involved in more than one LIFE-NAT project coordinated by Italian actors in the 2014-2020 period. Concerning coordinating beneficiaries, 7 actors coordinate more than one LIFE-NAT project. The highest numerosity of projects coordinated by the same coordinating beneficiary is 5.

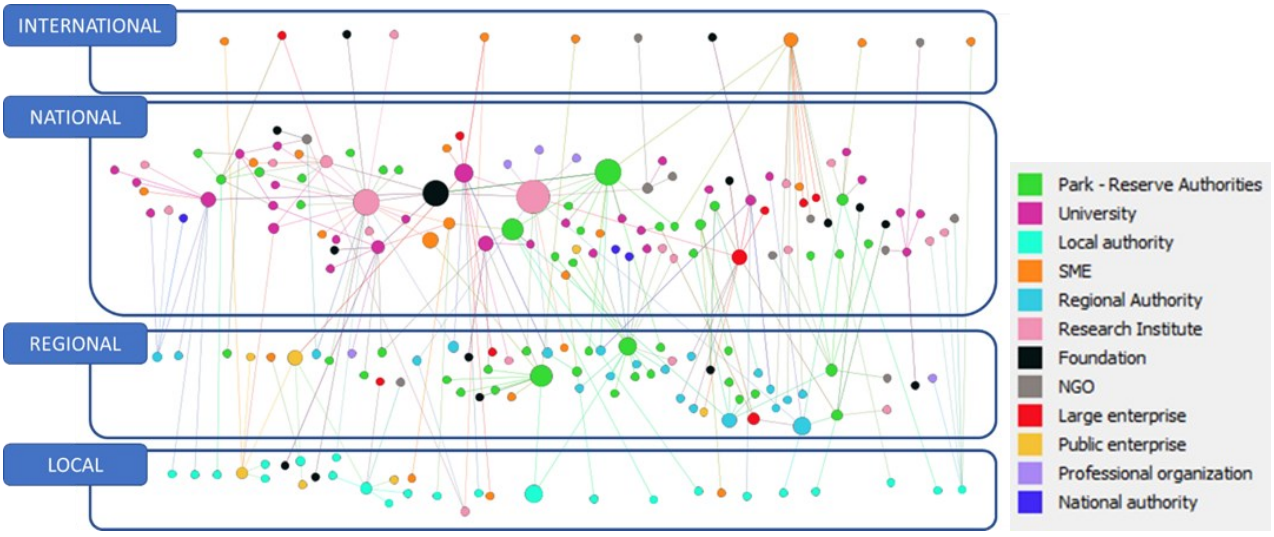


*Figure 3.1: Network composed of beneficiaries of LIFE-NAT projects coordinated by Italian actors in 2014-2020 period related through project partnerships. Source: our elaboration from LIFE Database through GEPHI ®.*

Many projects are characterized by transnationality (21 out of 45 projects). The network, composed mostly by Italian beneficiaries (74.4%), also involved actors from Spain (4.76%), France (4.29%), Hungary (2.86%), Greece (2.38%), Romania (1.9%), Slovenia (1.43%), Cyprus (1.43%), Austria (0.95%), Finland (0.48%), Albany

(0.48%), Croatia (0.48%), Tunisia (0.48), Malta (0.48%), Belgium (0.48%), Czech Republic (0.48%), Turkey (0.48%), Germany (0.48%). It reveals that collaborations based on the implementation of LIFE-NAT projects are more frequent between beneficiaries placed in the Mediterranean area and Eastern Europe.

#### 3.3.1.1 Analysis of multi-actor and multi-level governance

*Q1. To what extent and in which way LIFE-NAT projects promote a multi-actor and multi-level governance? How are LIFE projects partnerships consequently structured?*

In order to address Q1, we firstly focus on the composition of the network, and then we analyze homophily in relationships established by actors.

*Multi-actor governance*

Considering the typologies of actors, Park – Reserve authorities is the typology most involved in LIFE-NAT projects with 46 nodes in the network. It is followed by: universities (30), local authorities (23), SMEs (22), regional authorities (21), research institutions (19), foundations (15) and NGOs (11). A minor number of nodes belongs to large enterprise (9), public enterprise (7), professional organization (5), and national authority (3) categories. Even if the category "park-reserve authority" is the most present in the analyzed network, it is not possible to automatically consider park-reserve authorities as the most central actors, because they could be positioned in the peripherical areas of the network having only the role of associated beneficiaries without any role in the coordination of projects and spreading of information and resources. In order to clearly distinguish central actors, it is useful to identify what actors play the proactive role of coordinating beneficiary. Selected LIFE-NAT projects are mainly coordinated by park – reserve authorities (14 projects), universities (10 projects) and research institutions (9 projects). Regional and local authorities coordinate 3 projects, NGOs and SMEs coordinate 2 projects and large and public enterprises coordinate 1 project.

The general homophily value referred to the multi-actor governance calculated for the network is 0.64, in the E-I Index range of -1 - +1, attesting the presence of heterophily among actors, and consequently demonstrating that the LIFE Programme, in this case, catalyzes a multi-actor governance approach. Accordingly, figure 1 shows that most of the edges among nodes connect nodes with different colors.

Going deeply, we analyze the density of edges (relationships) between actors, *i.e.,* the ratio between the numerosity of edges between two specific and selected types of actors, subdivided for the total edges in the network. Figure 3.2 shows a network representing densities of connections between the diverse typologies of beneficiaries. The value of calculated density is written in the ellipsis positioned above the line characterized by its same color and connecting the typologies of actors selected for the calculation of density. Colors of the edges have only the function to make clearer the figure. Values which do not connect two different types of actors, in the grey ellipsis, show densities of homophilic relationships, meaning relationships between actors characterized by the same typology. According to the E-I index, it is possible to see that the analyzed network of LIFE-NAT beneficiaries is composed of nodes relating to multiple categories of actors. Nevertheless, nodes pertaining to categories like park-reserve authorities, universities, regional authorities, local authorities, and SMEs are more transversal than others. The highest value of density is related to a homophilic relation, *i.e.* the relation among park-reserve authorities themselves (8.7), followed by various heterophilic relations, included those between park-reserve authorities and universities (7.9), park-reserve authorities and research institutions (6.6), park-reserve authorities and regional authorities (6.2), research institutions and universities (4.1), research institution and SMEs (3.3), universities and regional authorities (3.3), park- reserve authorities and local authorities (3.3), research institutions and regional authorities (3.3).

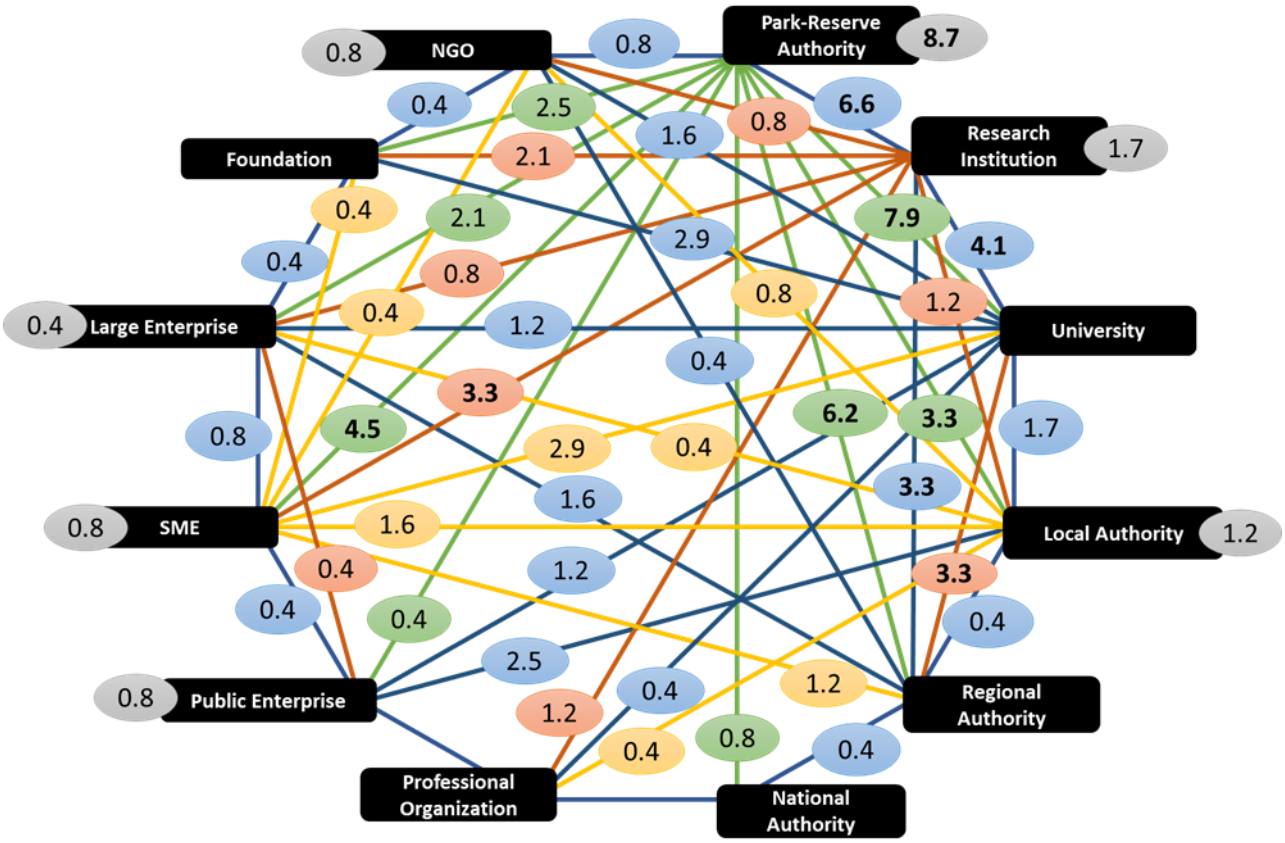


*Figure 3.2: Densities in relationships based on the typology of beneficiaries composing LIFE-NAT partnerships. Source: our elaboration from LIFE Database.*

*Multi-level governance*

Considering the level of beneficiaries along the jurisdictional scale, as evidenced by figure 1, most of the actors involved in selected LIFE-NAT projects operate at a national scale (103), followed by actors operating at a regional scale (64). The analyzed governance network is also constituted by fewer international and local actors, respectively 12 and 32.

Most of the selected LIFE-NAT projects are coordinated by actors operating at the national level (30 projects) and by actors operating at the regional level (9 projects). In addition, 1 project is coordinated by an actor having an international jurisdictional level, and 5 are coordinated by actors having a local level.

The homophily general value calculated for the multi-level governance network is 0.08, in the E-I Index range of -1 - +1, attesting actors tend to establish relationships with beneficiaries acting on both a similar and different jurisdictional level. The value, indeed, is quite near to 0, which indicates that there is no homophily nor heterophily. Analyzing homophily for both the scales “typologies of actors” and “jurisdictional level” is

needed because a specific type of actors does not have to coincide with a specific jurisdictional level (*e.g.*, park-reserve authorities can have a regional or a national jurisdictional scale). In practice, results of E-I values related to types of beneficiaries and jurisdictional levels reveal that partnerships of selected LIFE projects are often composed by diverse types of actors who necessarily do not operate at different jurisdictional levels.

Similar to Figure 3.2, Figure 3.3 shows densities of relationships based on the jurisdictional level of every involved actor. The highest density value is related to a homophilic relationship, meaning the relationship between beneficiaries acting at the national jurisdictional level (33.6). The other relevant value relies on the heterophilic relationship between actors having a national and a regional scale (29).

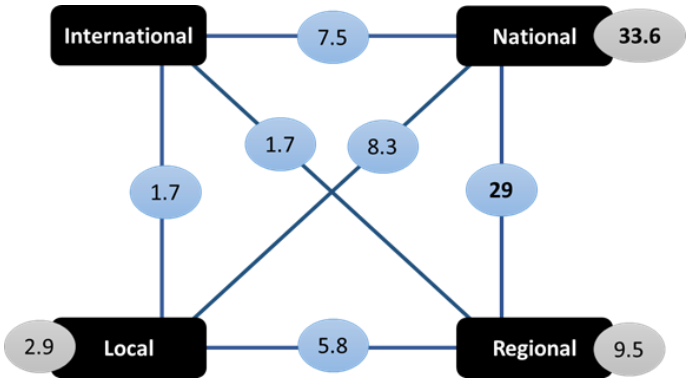


*Figure 3.3: Densities in relationships based on jurisdictional scales of beneficiaries composing LIFE-NAT partnerships. Source: our elaboration from LIFE Database.*

**3.3.1.2 Analysis of central actors.**

*Q2. What are the most important actors in the network of beneficiaries involved in selected LIFE-NAT projects? Do central actors have similar characteristics?*

By calculating degree and betweenness centrality, it is possible to identify central actors of the analyzed network which have the most important role in ensuring the flow of information and resources through connecting nodes. Additionally, we also identify actors characterized by the highest amount of EU co-financing allocated to each actor and obtained through the selection of LIFE-NAT projects by the EU Commission. Considering the EU co-financing as one indicator of the responsibility attributed to every beneficiary for the achievement of LIFE programme objective, through the implementation of projects, we want to verify if characteristics of the most central actors (*i.e.*, type of actor and jurisdictional level) are the same of the most funded actors. In this way it will be possible to identify what typologies of actors and

jurisdictional levels are most suited for LIFE programme purposes. In effects, central actors (*i.e.,* actors with the highest values of degree and betweenness centrality) should need more economic resources for their tasks which might include actions required for the implementation of projects (*e.g*., concrete actions for nature and biodiversity), but also project coordination and dissemination of results.

Figure 3.4 represents, through the use of positions and colors, typologies and jurisdictional levels of actors having (i) the highest value of degree centrality (fig. 3.4a), (ii) the highest value of betweenness centrality (fig. 3.4b) and (iii) the highest EU co-financing (fig. 3.4c). It highlights that park-reserve authorities, research institutions and universities are generally the most important actors involved in selected LIFE-NAT projects. In particular, the research institution category and park-reserve authorities are characterized by respectively the presence of the node with the highest value and the highest number of nodes, referred for all attributes here analyzed (*i.e.,* degree centrality, betweenness centrality, EU co-financing). Figure 3.4 shows that the NGOs and foundations are not amongst the most important actors in terms of centrality and financial resources allocated, even if one foundation is relevant in term of betweenness centrality. Considering private actors representing the market category (Lemos and Agrawall, 2006), SME is the category more recurrent in all analyzed attributes. The regional and local authorities are more present in fig. 3.4b, meaning they play better the role of brokerage. Comparing fig. 3.4a and b with fig. 3.4c, we compare centrality values with EU co-financing. This helps to demonstrate that not always nodes receiving the highest number of resources are the most central in the network of actors. For example, local authorities play an essential role in connecting nodes even if they are not relevant in the EU co-financing. Conversely, an NGO with a very high EU co-financing does not have a central role in the brokerage network. National authorities and professional organizations, which are present in fig. 3.4c are even not considered in fig. 3.4a and 3.4b, meaning that they have a null value in the connection of other nodes despite their relevant EU co-financing. Such results could be justified considering the competences assigned by the law and the suitability with tasks assigned to the actor in the project. For example, local authorities inevitably facilitate the flow of information among actors in their territories, because they usually do it for their ordinary activities and roles, so they do not need any additional economic resource from EU. To the other hand, such results could be used to better integrate intrinsic features of beneficiaries with the governance of LIFE projects in order to identify fundamental actors and the combination of beneficiaries most suitable for the LIFE programme purposes.

Considering the jurisdictional level associated with every actor, it is possible to observe that national and regional actors have the highest values for degree centrality, betweenness centrality and EU co-financing. Accordingly, universities and research institutions which have a national jurisdictional level are the most central and most funded actors. Comparing fig. 3.4 a, b with fig. 3.4c, we can observe that local levels tend to have a more important role in connecting nodes (*e.g.*, local authorities). Conversely, international level is more recurrent in actors with high EU co-financing. Park-reserve authorities is the category with the highest heterogeneity in jurisdictional levels. Focusing on park-reserve authority nodes, it is possible to see the compresence of beneficiaries having both a national and a regional position.

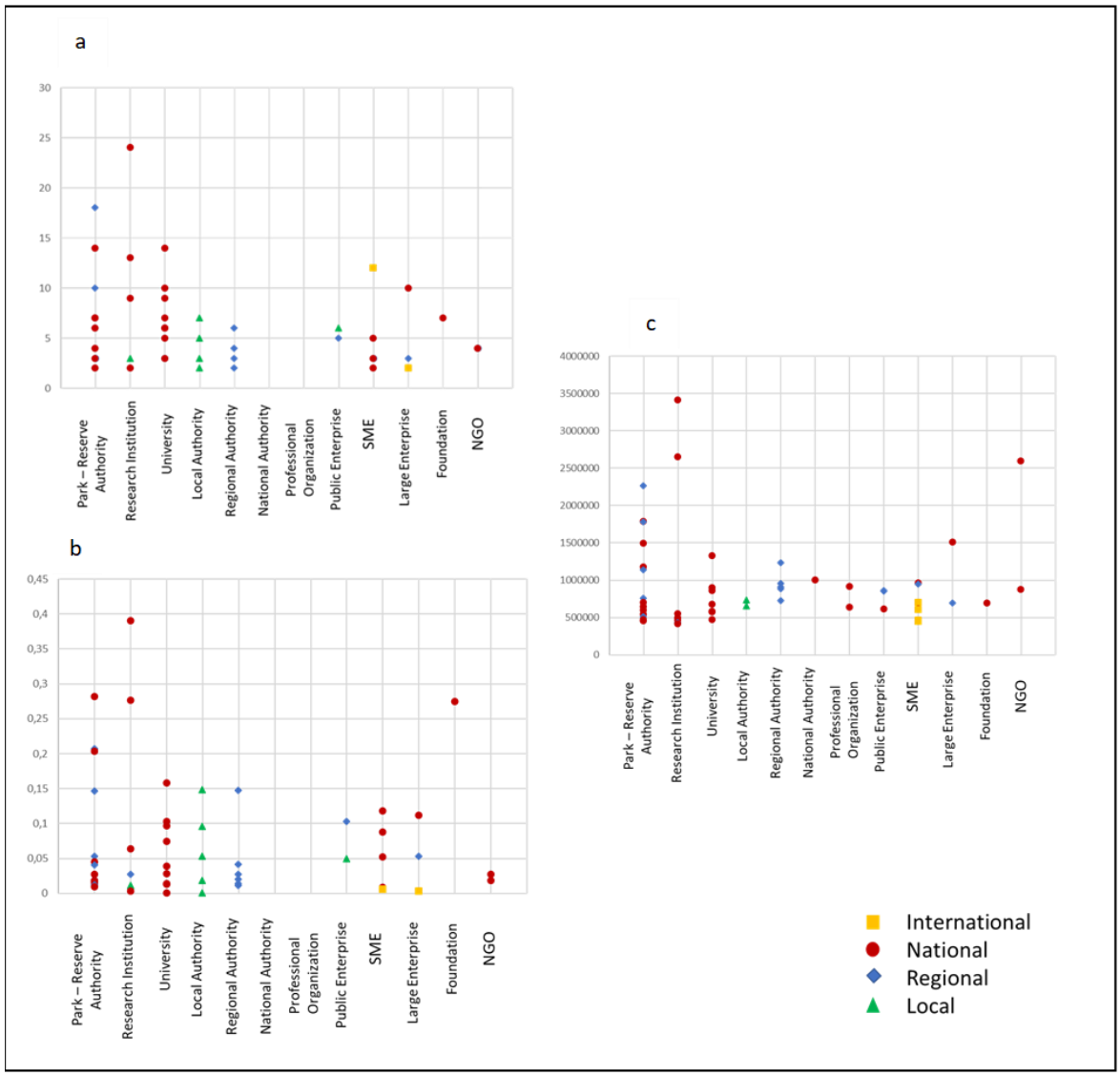


*Figure 3.4: Most important actors in the network referring to (a) degree centrality value, (b) betweenness centrality value, (c) EU co-financing. Sources: Our elaboration from LIFE Programme Database and Financial Transparency System.*

### 3.3.2 Geographical analysis of collaborative governance hotspots sustained by LIFE-NAT projects.

Q3. *How the collaborative governance for nature conservation and biodiversity restoration is effectively concretized in the Italian territory through the implementation of LIFE-NAT projects? Are there any geographical hotspots of effective collaborative governance evidenced by LIFE-NAT projects implementation?*

In order to detect how collaborative environmental governance for nature and biodiversity is concretized in the Italian territory, we analyze the geographical distribution of the selected LIFE-NAT projects. Therefore, we identify geographical hotspots of experiences based on collaborative governance and sustained by the LIFE Programme.

Only 3 out of 45 LIFE-NAT analyzed projects do not implement specific actions in Natura 2000 sites. Selected projects act in 254 Natura 2000 sites - mainly placed in Italy (196 - out of 2358 total sites in the country (MiTE web site)). Moreover, 9 LIFE-NAT projects also involve Natura 2000 sites placed outside Italy, specifically 16 sites in Hungary, 14 sites in Greece, 11 sites in Spain, 6 sites in Romania, 4 sites in France and Germany, 1 site in Croatia, Slovenia and Cyprus. 32 Natura 2000 sites are involved in 2 LIFE-NAT projects, 1 is involved in 3 projects. 14 LIFE-NAT projects act also in marine areas, involving 32 Natura 2000 sites in Italy, 3 sites in Greece and France and 1 site in Croatia, Spain, Cyprus, and Slovenia. Natura 2000 sites involved in analyzed LIFE-NAT projects in Italy are highlighted in figure 5. Different colors represent the number of projects acting in the same Natura 2000 site.

Figure 3.5 shows that the highest density of Natura 2000 sites involved in LIFE-NAT projects (*i.e.,* a geographical hotspot of collaborative environmental governance) is localized in the centre of Italy, especially along the Apennines, in inner mountainous areas. Large Natura 2000 sites involved in LIFE projects are also placed in inner areas of Sardinia and Sicily. Conversely, in North Italy, sites are smaller, except for the Venice Lagoon and the Po Delta, and they are mainly placed in the Po Valley, near rivers and cities. In the Italian territory, LIFE-NAT projects are established in Natura 2000 sites which are for the 50% parts of national or regional parks, or marine protected areas or natural reserves defined and protected by the national law (L.394/1991).

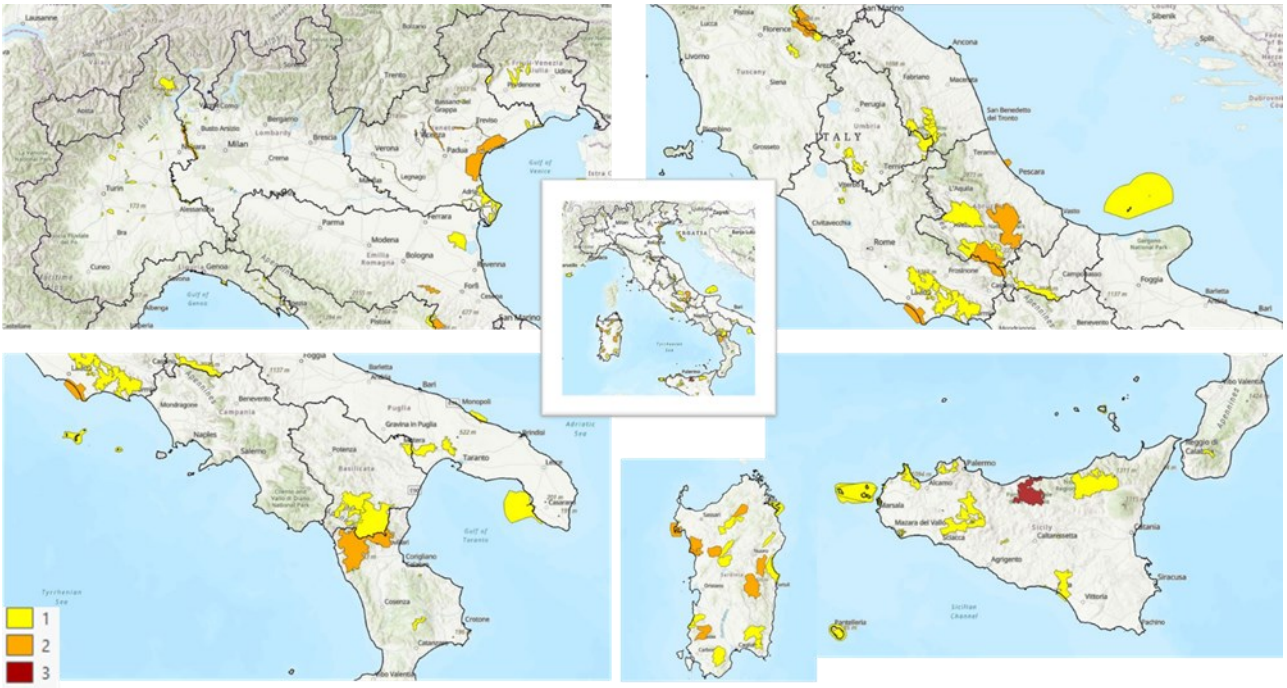


*Figure 3.5: Natura 2000 sites in Italy involved by the selected projects. Source: our elaboration from LIFE Database through ArcGIS ®*

**3.4 Discussion**

Results emerged from the analysis of collaborative governance in Italy fostered by LIFE-NAT projects are discussed in the following eight paragraphs.

*1. Results evidence a high degree of diversification in the typologies of actors involved in LIFE projects (i.e., public, private, for-profit and not-for-profit) and their participation in multiple governance levels. Thus, the LIFE Program has stimulated and supported collaborative governance for biodiversity preservation in the protected areas analyzed.*

The analysis of the composition of LIFE-NAT partnerships reveals the involvement of multiple typologies of actors in analyzed LIFE-NAT projects belonging to different jurisdictional level. Accordingly, figure 1 shows connections between nodes characterized by different colors, meaning different typologies of actors. Similarly, the E-I index value, 0.64, attests heterophily in relationships based on the scale “typology of actors”, thus demonstrating that the LIFE Programme has encouraged multi-actor collaborative governance for nature and biodiversity in the period analyzed. Indeed, the collaboration between different typologies of actors is fundamental to synergically face multiple environmental challenges affecting biodiversity caused by

human actions and identify trade-offs among multiple social needs (Andriollo *et al.,* 2021; Benetti and Langemeyer, 2021). Accordingly, in the Italian context, the literature proposes multiple experiences demonstrating the fundamental role of collaboration among multiple stakeholders (*e.g*., public authorities, NGOs, universities, fishermen, residents, tourism sector) in governance activities placed in protected areas, such as activities placed in the Marine Protected Area "Torre Guaceto" (Italy) able to lead the improvement of ecosystems and simultaneously provide economic benefits for locals (Russi, 2020); activities placed in "Alta Murgia" National Park (Italy) able to concretize sustainable development (Saviano *et al*., 2018a), and actions placed in "Abruzzo, Lazio and Molise" National Park (Italy) to develop best practices in the field of ecotourism (Salvatore *et al*., 2018). Conversely, lack of collaboration between multiple stakeholders could provoke conflicts, as described by Staniscia *et al.* (2019), focusing on Costa Teatina National Park (Italy).

*2. Results demonstrate a multi-actor composition, where public actors (e.g., protected areas authorities, local and regional authorities) represent the majority of partners involved in the LIFE-NAT projects. Conversely, results highlight the need to incentivize a higher involvement of private actors in LIFE-NAT partnerships.*

In fact, on the one hand and inevitably, public bodies (*e.g*., protected areas authorities, local and regional authorities) are the most important actors related to biodiversity protection activities, because of their prominent role assigned them by law in conserve or restore nature (Lai, 2020). Nevertheless, on the other hand, the literature highlights the importance to involve private actors and NGOs in order to ensure more effective governance of common goods, avoiding conflicts, identifying common strategies able to address the needs of stakeholders and making available more economic resources through public-private partnerships (*e.g*., Andriollo *et al*., 2021; Pisani *et al*., 2020; Malovrh *et al*., 2019; Nita *et al*., 2018; Pellegrino *et al.,* 2017; Secco *et al*., 2017). Additionally, the participation of private actors enhances the relevance of activities and ensures the prosecution of activities also after the end of projects because they are often local stakeholders benefitting the project outcomes (Benetti and Langemeyer, 2021). Nevertheless, private actors participating in LIFE-NAT projects as beneficiaries are especially services providers (*e.g*., energy utilities, recycling associations) or environmental consultants. Conversely, in this case study, there are very few examples of enterprises that effectively promote or benefit from ecosystem services derived from biodiversity. Moreover, LIFE-NAT projects composition highlights the importance of universities and research Institutions in participating in environmental activities, also as coordinating beneficiaries. They, indeed, can

lead innovative activities useful for conservation and restoration purposes (Romano *et al*., 2021; Russi, 2020; Holzer *et al.,* 2019; Secco *et al*., 2017), and they also have the skills for proposing and coordinating European projects, such as those funded by the LIFE Programme, which requires specific high-trained staff (Geitzenauer *et al*., 2017).

*3. The analysis confirms the fundamental role of protected areas authorities (e.g., national parks) in catalyzing collaborative environmental actions connecting all other typologies of actors (e.g., universities, research institutions, SMEs, and regional authorities) focused on nature conservation and restoration.*

The analysis of densities of relationships, indeed, shows that protected areas authorities make the highest number of relationships, connecting not only with each other but also with all other typologies of actors, especially with universities, research institutions, SMEs, and regional authorities, demonstrating once again, the capacity of the LIFE Programme to promote multi-actor collaborative governance. In accordance with results, the literature proposes protected areas authorities as catalyzers of collaborations related to nature conservation and restoration between different typologies of actors (Romano *et al*., 2021; Manolache *et al*., 2019; Martini *et al*., 2017; Bodin *et al*., 2016). Protected areas authorities, indeed, play a fundamental role in mediating relationships between different typologies of actors, especially between local actors and external actors equally involved in the environmental governance for biodiversity conservation and restoration, by encouraging new approaches able to improve both natural and socio-economic conditions of protected areas (*e.g*., Romano *et al.,* 2021; Russi, 2020). Moreover, results show the importance of collaboration between protected area authorities that manage different protected areas. As highlighted by the concept at the basis of the Natura 2000 network, any protected area cannot work in isolation (Brambilla *et al*., 2020). Conversely, the concept of connectivity operationalized through ecological networks is considered the answer to preserving healthy ecosystems and biodiversity (Gippoliti and Battisti, 2017; Martini *et al*., 2017). Additionally, the literature focused on environmental governance of protected areas highlights that facilitating social collaborations between stakeholders is equally important as realizing ecological connectivity (Alexander *et al*., 2017; Bodin *et al.,* 2016; Guerrero *et al.,* 2014) because "basing institutional design on ecological knowledge alone, without recognizing the fundamental impact of other institutions and social actors on ecological systems, is a simplistic approach that fails to appreciate the complexity of governance processes" (Galaz *et al*., 2008; p. 159). Cooperation and coordination among

different but connected administrations of protected areas (*i.e.,* the authorities in charge for their management) are needed in order to maintain such social and ecological networks, especially when they act at different institutional levels (*e.g*., regional as highlighted by LIFE Insubricus LIFE19 NAT/IT/000883).

*4. If, from one side, results evidence a high presence of actors at the national jurisdictional level, on the other side, the involvement of local actors is quite limited. Their reduced participation is probably due to the financial resources' requirements to the initiatives. However, local actors effectively work where LIFE-NAT projects intend to act. Local bodies, indeed, could enhance performances of environmental initiatives with a different modulation of their financial contribution.*

Looking at the jurisdictional level at which the LIFE-NAT project beneficiaries act, it appears that most actors act on a national or a regional level. The high presence of LIFE beneficiaries having a national level could be motivated by the need for relevance and credibility required for every actor benefitting a European co-financing (*e.g*., EC, 2013), also from an economic point of view. Consequently, if an actor considers its available resources insufficient, it will probably tend to avoid European co-financing (Geitzenauer *et al.,* 2017). This requirement could reduce the involvement of local actors, which very often are too small and with a limited amount of financial and human resources. In addition, small organizations, like the local ones, often have few capacities (*e.g*., organizational and linguistical) to directly use international funds (Secco *et al*., 2017). Additionally, LIFE-NAT projects are often well space-defined (Hermoso *et al.,* 2018), meaning they aim to address needs for a specific area that usually has a sub-national level (Paloniemi *et al*., 2012), such as the case of the Italian administrative regions. Consequently, LIFE-NAT partnerships tend to be composed of national, sub-national (regional) or – to a less extent, local actors - in spite of international actors because of their best suitedness in reaching place-based objectives (Manolache *et al*., 2018; Secco *et al.,* 2017; Paloniemi *et al.,* 2012). Moreover, beneficiaries acting at the national or regional level could be the ones responsible for the implementation and maintenance of the Natura 2000 network in the country or area (Geitzenauer *et al*., 2017) or could offer high-quality specialized skills required for the implementation of particular activities within a LIFE project (*e.g*., conservation measures in charge of universities in the LIFE project MedTurtles LIFE18 NAT/IT/000103). Additionally, NGOs with a national level can connect different actors and have the communicative tools to spread information broadly (Andriollo *et al*., 2021; Fossi *et al.,* 2020). Additionally, national NGOs could be central in the governance network because of their influence in the local policy (*e.g*.,

Manolache *et al*., 2018) and consequently they result necessarily involved in LIFE projects, as it is possible to see in the analyzed network where a national NGO is one of the most central nodes as associated beneficiary in multiple LIFE-NAT projects. However, interactions between actors acting at different levels are necessary to prevent divergences in conservation efforts at different levels, which are considered one of the drivers of European failures in nature conservation activities (Geitzenauer *et al*., 2017). Therefore, it is fundamental to encourage the involvement especially of local actors, which effectively work in places where LIFE-NAT projects intend to act. Local bodies, indeed, could enhance performances of environmental initiatives through their knowledge on specific needs, synergies and capacity to deal with trade-offs among multiple challenges to be addressed and through their capacity to lead participative processes among LIFE-NAT project partners and the community where activities are located (Hermoso *et al*., 2022; Andriollo *et al*., 2021; Laktić *et al*., 2020).

*5. Results indicate high horizontal collaborations only among national actors, revealing the need to proactively encourage sub-national actors to act as associated beneficiaries and coordinators. In this way, it should be possible to strengthen horizontal collaborations between stakeholders who effectively live and work in areas where LIFE-NAT projects are placed.*

The value of the E-I index shows there is no homophily nor heterophily in the jurisdictional scale, meaning that actors equally relate with actors acting within the same or in different jurisdictional levels. Specifically, the calculated densities of relationships highlight that actors relate especially in two ways: relationships between two actors having both a national level and between actors having a national and a regional level. The literature indicates the need for vertical and horizontal collaborations to ensure effective governance of ecosystems (Pahl-Wostl, 2019; Secco *et al*., 2017; Newig and Fritsch, 2009). The structure of the network of Italian LIFE-NAT project partnerships allows verifying the presence of collaborations established between coordinating and associated beneficiaries. In our case study, it is possible to appreciate vertical collaboration only between national and regional levels, revealing the need to better integrate all jurisdictional levels in LIFE-NAT projects in order to concretize the "Think global, act local" vision of sustainable development (Hermoso *et al*., 2022; Secco *et al*., 2017; Folke *et al*., 2016; Newig and Fritsch, 2009). Also, results indicate high horizontal collaborations only among national actors, revealing the need to encourage sub-national actors to proactively act not only as associated beneficiaries but also as coordinators, involving other bodies

acting at the same jurisdictional level. In this way, it should be possible to strengthen horizontal collaborations between stakeholders who effectively live and work in areas where LIFE-NAT projects are placed. In this way, it would be possible to design more relevant projects, able to better address site-specific ecological and socio-economic issues, catalyzing a sustainable development able to provide benefit to nature and society (Andriollo *et al*., 2021; Russi, 2020; Voghera, 2020).

*6. Protected areas authorities and research institutions are the most important actors in the analyzed network. Results show that local authorities are intrinsically suitable for collaboration purposes. Consequently, they should be encouraged to adopt more relevant roles in LIFE-NAT projects proposal and implementation, but this requires investments in capacity building and more strategical political visions. They need to be supported, especially by research institutions, universities or NGOs that can replicate and spread results broadly.*

As already discussed, protected areas authorities are fundamental in leading the governance of nature and biodiversity (Cumming, 2016). National research institutions with specific skills related to nature conservation and restoration are considered fundamental in catalyzing LIFE projects in order to address problems through the replication of good practices or introducing innovations (Russi, 2020; Salvatore *et al.,* 2018). Despite other European experiences related to the management of Natura 2000 sites (*e.g*., Laktić and Malovrh, 2018 in Slovenia, Manolache *et al*., 2018 in Romania), in the LIFE-NAT projects explored in our study actors representing the community or civil society (Lemos and Agrawal, 2006), as well as public authorities other than those in charge of protected areas are not so influential as expected, even if many public authorities are *de facto* in charge of the definition and/or implementation of conservative measures and management plans of Natura 2000 sites (Lai, 2020; Martini *et al*., 2017). Results shed light on the low capacity of public authorities other than parks to catalyze collaborations with other actors to stimulate the emergence of bottom-up initiatives (*e.g*., LIFE projects) able to improve the Natura 2000 top-down instrument created and regulated by the EU. In this regard, results indicate the bridging role of national research institutions and a national foundation, which, presumably, at present, fill in the gap (*e.g*., Fossi *et al*., 2020). Moreover, results show that local authorities are intrinsically suitable for collaboration purposes. Consequently, they should be encouraged to adopt more relevant roles in LIFE-NAT projects proposal and implementation, but this requires investments in capacity building and more strategical political visions. They need to be supported especially

by research institutions, universities or NGOs that can replicate and spread results broadly. Additionally, public funds could be integrated through the involvement of private bodies (Hermoso *et al*., 2022; Pisani *et al*., 2020; Martini *et al*., 2017). In this way, there would be the possibility to increase community support for conservative actions and increase their trust in public institutions that, to date, in Italy, is low (Hermoso *et al*., 2022; Tonin and Lucaroni, 2017).

*7. Results highlight that the collaborative governance for nature and biodiversity mainly occurs in areas where wildlife is recognized and valorized for its intrinsic value and its fundamental role in economic activities through the availability of ecosystem services. This result emerges equally in North and Centre-south Italy.*

Results show that LIFE-NAT projects are mainly located in Natura 2000 sites, confirming that the collaborative governance for nature and biodiversity in Italy is placed especially in protected areas. Looking at the geographical distribution of Natura 2000 sites where LIFE-NAT projects are implemented, it is possible to clearly distinguish differences in the concretization of a collaborative governance for nature and biodiversity between the North and the Centre-South of Italy, not only due to ecological (Giupponi *et al.,* 2021; Gigante *et al*., 2018) but also to socio-economic differences (Romano *et al*., 2020). Nevertheless, results highlight that the collaborative governance for nature and biodiversity takes place especially in areas where nature is recognized and valorized not only for its intrinsic value but also for its fundamental role in economic activities through the availability of ecosystem services, equally in North and Centre-south Italy. In particular, collaborative governance for nature and biodiversity in the North of Italy takes place mainly through LIFE-NAT projects implemented in very small Natura 2000 sites located in the Po Valley, especially along rivers. The largest Natura 2000 sites in this area, located mainly in the Alps, are not involved in LIFE-NAT projects. LIFE-NAT projects, in this case, could be considered tools able to valorize and restore habitats placed in a geographic region not favorable for nature and biodiversity purposes (Sallustio *et al*., 2017) that, in turn, is characterized by peculiarities in habitats and species (Iannella *et al.,* 2020). In fact, the Po Valley is considered one of the most urbanized and polluted areas in Italy, with the highest levels of industrialization and intensive farming (both agriculture and livestock), which causes an environmental fragmentation that negatively affect the quality of landscapes (Romano *et al.,* 2017) and nature (Chetan and Dornik, 2021). Nevertheless, Po Valley is characterized by the national highest levels of aquatic plant diversity, especially in Lombardy and Veneto regions (Bolpagni *et al*., 2018) and provides unique habitats for migratory species like cranes (EEA, 2012).

Characteristics of Natura 2000 sites placed in North of Italy where selected LIFE-NAT projects are located suggest that the collaborative governance for nature and biodiversity tend to focus on restoration of habitats and species and their valorization, not only to enhance the management of nature but also to provide new ecosystem services in a very populated area, making people aware about biodiversity conservation and restoration challenges, *e.g*., Life PollinAction LIFE19 NAT/IT/000848, Life Brenta 2030 LIFE18 NAT/IT/000756 (Battisti *et al*., 2019). Focusing on Centre-South of Italy, it is possible to appreciate the implementation of a collaborative environmental governance based on LIFE-NAT projects in larger Natura 2000 sites in the Apennines, which often belong to national or regional parks and are mostly located in inner and mountainous areas. Those are areas with an important natural and cultural capital, which are also characterized by reduced access to public services and infrastructures and, consequently, low social and economic development opportunities. In the Italian context, such areas are now characterized by multiple problems related to depopulation and the abandonment of traditional activities (Marucci *et al*., 2020). In this case, the collaborative governance for nature and biodiversity has not only the objective to conserve biodiversity merely but also to catalyze activities able to create opportunities for sustainable development based on the valorization of nature, making locals aware of the natural and cultural value characterizing such areas, *e.g*., Life Nat.Sal.Mo. LIFE17 NAT/IT/000547, Life FloraNet LIFE15 NAT/IT/000946 (Salvatore *et al*., 2018; Saviano *et al*., 2018a). In this sense, sustainable tourism and traditional food and specialties production are two key elements for the emergence of new opportunities of these inner and marginalized areas (Buongiorno and Intini, 2020, Salvatore *et al*., 2018; Schirpke *et al*., 2018).

*8. Results evidence that the emergence of collaborative governance for nature and biodiversity is better stimulated by the presence of specific authorities which manage protected areas, like parks authorities, revealing the added value of Natura 2000 sites overlapped to protected areas regulated by the national law (L.394/1991).*

The high presence of Natura 2000 sites embedded in national or regional parks, natural reserves and marine protected areas demonstrates that the emergence of collaborative governance for nature and biodiversity is better stimulated by the presence of specific authorities which manage protected areas, like parks authorities, revealing the added value of Natura 2000 sites overlapped to protected areas regulated by the national law (L.394/1991). Accordingly, the literature highlights that the governance of protected areas like

national parks better addresses conservation issues and needs than the governance of protected areas that belong only to the Natura 2000 network (Sallustio *et al*., 2017). The latter, in fact, is composed by multiple and heterogeneous bodies designated to implement conservation activities which coexistence weakens the management of sites, *e.g*., reducing possibilities in obtaining opportunities for funding or making more difficult the emergence of synergies among different stakeholders (Pellegrino *et al.,* 2017). Additionally, sites belonging only to the Natura 2000 network often do not have an official management plan to harmonize local needs with objectives settled by the main strategies at the national and EU level (Lai, 2020; Sallustio *et al.,* 2017). In this sense, to harmonize local needs with national or international objectives, is fundamental the role of specific bodies able to act as bridges between different jurisdictional levels that necessarily are involved in the management of biodiversity (Pecurul-Botines *et al.,* 2019; Secco *et al*., 2017; Lockwood, 2010), and between different types of beneficiaries (Schmidt *et al*., 2020; Nita *et al.,* 2018; Hossu *et al*., 2017). Very often such intermediations happen in protected areas recognized also as national or regional parks, as highlighted by experiences placed in protected areas located in the Abruzzo region, which is recognized as the greenest region of Europe (Di Giacobbe *et al.,* 2021), and here identified as one of the main hotspot of effective collaborative governance for nature and biodiversity, *e.g*., Gran Sasso and Laga Mountains National Park (Salvatore, 2015), Majella National Park (Colecchia, 2019; Sjölander-Lindqvist and Cinque, 2014), and Abruzzo National Park (Holloway *et al*., 2006).

**3.5 Conclusions**

With this research focused on Italy, we aim at verifying if the EU LIFE Programme catalyzes a collaborative governance for nature and biodiversity and measuring the extent in which it has supporting the emergence of collaborative governance, supporting both multi-actor and multi-level collaborations in proactive activities placed mainly in protected areas. Natura 2000 European network is the biggest network of protected areas in the world. Increasing the number, enlarging the area, and enhancing the governance of protected areas is considered a key strategy for biodiversity conservation and ecosystems restoration, both in current days and in future. The EU is incentivizing the improvement of these protected areas management especially through the co-funding of projects, such as those realized under the LIFE Programme. Specifically, LIFE could be considered an EU Programme suited to stimulate environmental projects based on collaboration principles by creating partnerships of multiple actors that propose and implement projects. Our analysis demonstrates

the suitability of the LIFE Programme in supporting a multi-actor governance for nature and biodiversity. In particular, protected areas authorities appear the actors most prone to stimulate collaborative governance for nature and biodiversity among multiple typologies of actors through their capacity to mediate local needs with environmental objectives, supported by third-sector bodies such as universities, research institutions, or NGO-foundations. Protected areas authorities, indeed, can sustain also a multi-level governance through the catalyzation of relationships especially between actors acting at national and regional levels, by means of the creation of partnerships that develop and implement LIFE-NAT projects. The fundamental role of protected areas authorities and the recognition that half of Natura 2000 sites involved in LIFE-NAT projects belongs to national or regional parks show the value-added of having Natura 2000 sites geographically overlapped to sites regulated by a previously existing national law for protected areas. In fact, weaknesses in the management of protected areas belonging only to the Natura 2000 network appear in connection with a lack of coordination between multiple authorities in charge of conservation activities. The analysis of the network composed by LIFE-NAT beneficiaries highlights the need to better integrate local bodies, especially local authorities and private companies, which effectively benefit from ecosystem services improved by LIFE-NAT projects but do not contribute significantly to their creation and implementation.

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Conceptualization, E.A., E.P., and L.S.; methodology, E.A. and E.P.; data curation, E.A.; writing—original draft preparation, E.A.; writing—review and editing, E.A., E.P., and L.S.; supervision, E.P., L.S., and A.C. All authors have read and agreed to the published version of the manuscript.

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## Chapter 4: Paper 3

***Probabilistic Network Analysis of Social-Ecological Relationships emerging from EU LIFE Projects for Nature and Biodiversity: an Application of ERGM models in the Case Study of the Veneto region (Italy).***

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**Highlights**

● A polycentric governance structure does not necessarily determine a multi-actor and multisector governance.

● Collaborations of different LIFE projects in an N2000 site overcome the limits of a single intervention.

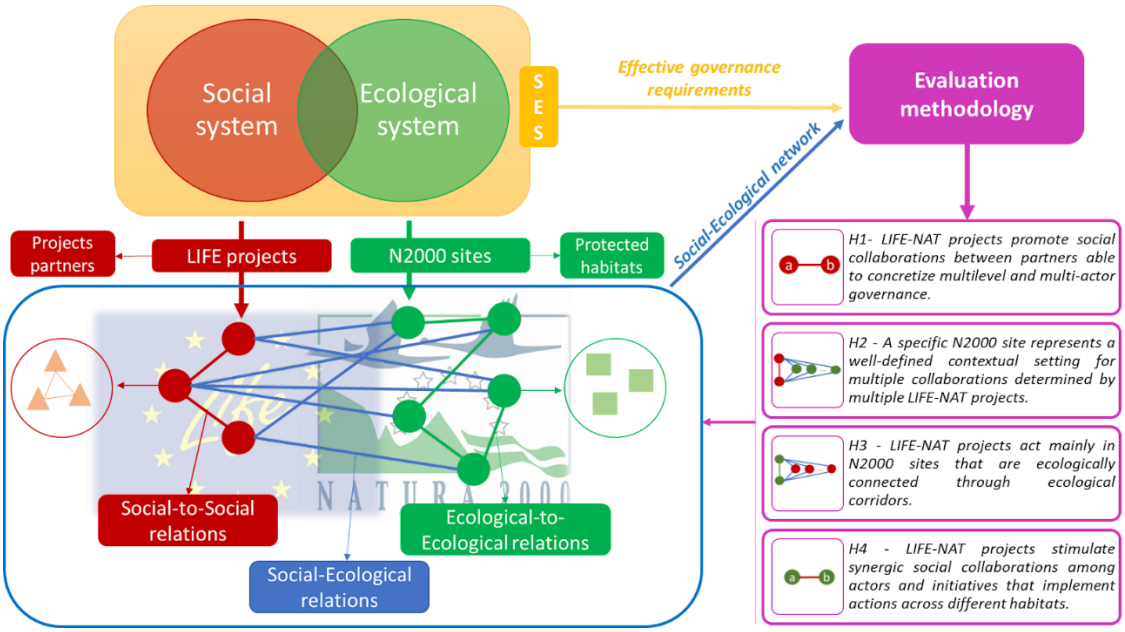
● LIFE projects foster synergies across marine, land and freshwater ecosystems promoted by the transversal role of forests.

**Abstract**

Considering social-ecological relationships in managing protected areas is fundamental to ensuring effective biodiversity conservation and restoration governance. Network analysis offers valuable methods to disentangle intangible relations between and within the social and ecological systems. In this way, it could be possible to identify and integrate multiple social and ecological variables that inevitably affect collaborative environmental governance's effectiveness. Nevertheless, this research area is still nascent, with few methodologies and concrete applications reported in the scientific literature. With this study, we aim to

propose a robust novel application of a network methodology to enrich the evaluation of the effectiveness of collaborative environmental governance for nature and biodiversity, which has been applied through the analysis of social-ecological relationships that emerged from EU-cofounded LIFE-NAT projects. Specifically, we focus on LIFE-NAT projects implemented in the Veneto Region (Italy) financed in the last programming period (2014-2020). Through formulating four research hypotheses to be tested through Exponential Random Graph Models, we analyze 13 LIFE-NAT projects involving 83 social actors and 29 Natura 2000 (N2000) sites composed of 57 protected habitats. Results show that LIFE-NAT projects in Veneto Region stimulate polycentric governance. Nevertheless, they still need to concretize a multi-actor and multilevel governance. Furthermore, the analysis highlights that selected LIFE-NAT projects implement activities in N2000 sites able to support ecological connectivity and synergies across marine, freshwater, and land habitats through the bridging role of forests, especially in estuarine and coastal areas.

**Graphical Abstract**




*Keywords: Environmental Collaborative Governance, Biodiversity Conservation, Social-Ecological Relationships, Social-Ecological Network, Exponential Random Graph Modeling, EU LIFE Projects, Ecological Connectivity, Protected Habitats.*

### 4.1 Introduction

Recognizing and valorizing interdependencies between society and ecosystems constitute a real challenge to face ongoing environmental problems effectively (Munck af Rosenschöld and Vihma, 2022; Bodin, 2017; Folke *et al*., 2016; Bodin *et al*., 2014). Biodiversity degradation, in particular, is one of the most current pressing environmental threats due mainly to human activities, showing that humanity has become a significant force able to foster negative changes at the planetary scale (Roberts *et al*., 2019; Folke *et al*., 2016). According to IPBES (2019), humanity is currently experiencing the sixth species extinction, with 1 million species threatened by an increasingly faster extinction rate (Ceballos *et al*., 2020). To face this problem, one of the essential tools used by environmental governance is the creation of protected areas, which is helpful in the promotion of biodiversity restoration and conservation (Negacz *et al*., 2022; Cumming *et al.,* 2015). In line with this vision, in the European context, the new EU Biodiversity Strategy targets increasing up to 30% of land and 30% of marine area under protection by 2030 (COM(2020) 380). Nevertheless, even if the size of protected areas has increased in recent years, biodiversity continues to decline (Hermoso *et al*., 2022; Rada *et al*., 2018), demonstrating that biodiversity conservation initiatives, at present, have failed to achieve their conservation and restoration objectives (Xu *et al*., 2021; Gavin *et al*., 2018). Martín-Lopez and Móntes (2015) identify the absence of a systemic vision in traditional conservation governance, which focuses on relations between human society and the biophysical system, as one motivation for its failure. In the scientific literature, the fundamental value of social-ecological interactions is highlighted by the Social-Ecological System (SES) concept, which underlines that society is a component of the biosphere and, thus, entirely dependent on nature (Folke *et al*., 2016; Chaffin *et al*., 2014). This view has been consolidated in recent years, especially during the Covid-19 pandemic, through the emergence of the "*One Health Approach*", which highlights that human and animal health is inevitably connected with ecosystems' health (Gruetzmacher *et al*., 2021).

In the European Union (EU) conservation policy framework, the valorization of social-ecological interdependencies is emphasized by the Natura 2000 (N2000) network. It represents an invaluable example of large-scale conservation initiative based on a uniform system of protected areas across the whole EU territory (Campagnaro *et al*., 2019), proving to be the largest integrated system of protected areas in the world, covering 18% of EU land area and 8% of EU marine area. It was created in 1992 through Habitat

Directive - 92/43/EEC, and it is composed of protected sites that include areas fundamental for the life of rare and threatened species or protected habitats. Protected sites are not limited to areas characterized by remoteness but also include parcels located in highly urbanized areas with different economic interests (Campagnaro *et al*., 2019). In effect, the main objective of the N2000 initiative is to promote biodiversity conservation taking into account both ecological and socio-economic needs (92/43/EEC). Given the centrality of the N2000 network in EU conservation endeavors, it represents the core of the EU conservation approach, which needs to be consolidated, supported, reinforced, and valorized (Hermoso *et al.*, 2022; Campagnaro *et al.,* 2019; Hermoso *et al*., 2017). The LIFE Programme represents the primary financial source able to sustain N2000 network management (Hermoso *et al*., 2022; Campagnaro *et al*., 2019; Hermoso *et al*., 2017; Sánchez-Fernández *et al*., 2017). More generally, the LIFE Programme focuses on multiple environmental challenges which need to be faced by EU society, through multiple LIFE projects concerning different priority areas (*e.g*., nature and biodiversity, resource efficiency, climate change adaptation and mitigation)(EU R. n. 1293/2013, preamble 3). Focusing on nature and biodiversity challenges, LIFE is the only EU-funded programme specifically and directly focused on biodiversity conservation and restoration, so it ensures the real implementation of in situ conservation initiatives on N2000 sites (Hermoso *et al.,* 2017). Additionally, the LIFE Programme could be considered an EU tool able to stimulate the emergence of collaborations between multiple and different actors across EU territory, bringing multiple actors through collaboration based on shared objectives to face everyday challenges, thus, constituting a real and tangible example of collaborative environmental governance (CEG) (Munck af Rosenschöld and Vihma, 2022).

To ensure effectiveness in biodiversity activities promoted by CEG initiatives like LIFE-NAT projects in N2000 sites is fundamental recognizing that biodiversity concept does not focus only on the diversity of species and habitats but also on the multiple ways in which social and ecological components relate, assuming different configurations and structures which need to be identified to ensure effectiveness of conservation initiatives (Cummin *et al*., 2015; Bodin *et al*., 2014; Bodin *et al*., 2019). In particular, the social-ecological fit concept underlines the fundamental importance of considering connectivity and interdependencies between social actors and ecological components in order to avoid or solve problems related to environmental management (*e.g*., asymmetrical use or overuse of natural resources, cascading effects like the spread of invasive alien species, or the depletion of key species in ecosystems), which reveals that very often borders of social activities do not match with ecological borders (Bodin, 2017; Guerrero *et al*., 2015). CEG could present a

valuable solution to face social-ecological fit challenges (Bodin *et al*., 2016). Nevertheless, collaboration could not be seen as a panacea solution. However, it must be oriented in order to foster effectiveness in CEG through the identification of structural configurations mostly fitted to environmental challenges they need to face (*e.g*., more centralized if the problem is urgent, more inclusive when problems cover multiple economic resources) (Andriollo *et al*., 2021; Bodin, 2017; Bodin *et al*., 2016; Bodin *et al*., 2014).

One approach able to integrate social and ecological components affecting CEG is the Social-Ecological Network (SEN) approach based on network analysis (Barnes *et al*., 2019; Bodin *et al*., 2019; Sayles *et al*., 2019; Bodin *et al*., 2016). Even if network approaches focusing on both social and ecological components of CEG have recently increased, this new research area is still nascent, with a few methodologies and applications reported in the scientific literature (Xiu *et al*., 2017; Sayles *et al*., 2019; Bodin *et al*., 2019). To contribute to such efforts, the specific objective of this study is to propose and validate a robust novel application of network approach able to enrich the evaluation of effectiveness of the EU collaborative environmental governance through the analysis of social-ecological relationships stimulated by EU co-funded LIFE projects proposed by partnerships. This could be a tool that can offer an additional perspective complementary to other evaluation methodologies already proposed in the literature, focusing specifically on social-ecological interactions through the verification of four hypotheses (Section 2). In this way, it will be possible to provide operative indications to agencies and partnerships on how: (i) to improve social collaborations involved in CEG, (ii) to increase the social-ecological impact of environmental activities, and (iii) to stimulate a shared environmental responsibility.

After this introduction, we outline our conceptual framework drawing four propositions (*i.e*., research hypotheses) focused on EU LIFE-NAT projects (Section 2). Then, we present our methodological framework, introducing core concepts, network approaches, and data used for our analysis (Section 3). Next, we verify research hypotheses through ERGM models showing and describing results (Section 4). We discuss the results in the discussions section (Section 5). The article concludes with final remarks (Section 6).

### 4.2 Conceptual framework and related research hypotheses

This study aims to reach its main objective by verifying four different research hypotheses that synthesize features able to foster effectiveness in CEG as emerging from experiences reported in the scientific literature.

Each hypothesis is translated into specific network structures, which are then verified through Exponential Random Graph Modeling (ERGMs), as proposed by Bodin *et al*. 2017; Guerrero *et al*., 2015; Bodin *et al*., 2014 (see Section 3)

*H1 - LIFE-NAT projects promote social collaborations between partners able to concretize multilevel and multi-actor governance*. Complexities characterizing environmental challenges require hybrid governance approaches able to integrate different typologies of actors (*i.e*., the State, market and community), which cannot face environmental problems alone (Lemos and Agrawal, 2006). Therefore, effective collaborations need to include such different groups of actors, connecting them horizontally, across a single jurisdictional level, and vertically across multiple jurisdictional levels (Rigo *et al.,* 2022; Alexander *et al*., 2017). In this way, partnerships could be more prone to identify shared solutions that overcome jurisdictional boundaries and minimize conflicts and misunderstandings among different stakeholder groups (Andriollo *et al*., 2021; Alexander *et al*., 2017; Bodin and Crona, 2009). This capacity is essential in conservation initiatives, which very often are limited by local conflicts generated by local communities who feel exposed to new rules and initiatives that typically originate at higher jurisdictional levels (*e.g.* at the EU level), potentially limiting their economic activities at the local level (Munck af Rosenschöld and Vihma, 2022; Romano *et al*., 2021; Staniscia *et al.,* 2019).

*H2 - A specific N2000 site represents a well-defined contextual setting for multiple collaborations determined by multiple LIFE-NAT projects***.** Suppose social actors share objectives and agree on common rules or interventions. In that case, they could use resources more efficiently, compared to the situation where all social actors act individually. They could coordinate efforts concerning the specific characteristics of the N2000 site, avoiding redundant activities, as demonstrated by Bodin *et al*. (2014) and Guerrero *et al*. (2015). In LIFE projects, this requirement is already intrinsically embedded in the partnership concept (Munck af Rosenschöld and Vihma, 2022). By adopting a broader vision, the LIFE program to be effective requires collaboration even among different LIFE projects which act in the same area. The wide area approach implemented through diverse projects facilitates a multiplier effect in terms of nature protection and conservation that can help to concentrate the efforts towards a commonly defined strategic and coherent vision, as well as optimize the use of limited-inadequate resources often allocated for biodiversity conservation purposes (Hermoso *et al*., 2022; Holzer *et al.,* 2019; Popescu *et al.,* 2014).

*H3 - LIFE-NAT projects act mainly in N2000 sites that are ecologically connected through ecological corridors.* Environmental interventions, like LIFE-NAT projects, aim to replace ecological connectivity to achieve social-ecological fitness of social activities (Bodin, 2017). Accordingly, the network of protected areas realized through N2000 is considered more successful if it can connect multiple protected sites through ecological corridors to allow the movement of species (Hermoso *et al*., 2022; de la Fuente *et al.,* 2018). Furthermore, ecologically interdependent areas require particular efforts of coordination among interventions and coherent management practices to avoid limited adverse effects which could emerge from isolated management of protected areas, like the spreading of invasive species (Bodin *et al*., 2019; Bodin, 2017). This explains why conservation initiatives supported by LIFE-NAT projects need to consider the whole ecosystem in which they act, proposing activities in multiple interconnected areas which represent a different part of the same ecosystem in which they are embedded (Bodin, 2017).

*H4 - LIFE-NAT projects stimulate synergic social collaborations among actors and initiatives that implement actions across different habitats.* Conservation efforts must synergically act across freshwater, terrestrial and marine realms (Hermoso *et al*., 2022; Hilty *et al*., 2020; Hermoso *et al*., 2017) to increase connections between different but interdependent habitats (Bodin, 2017). As for H3, ecosystems need to be managed as complex systems composed of multiple entities (biotic and abiotic factors and their reciprocal interdependencies), avoiding focusing on a single aspect or component representing only a portion or sub-system of an ecosystem (Bodin, 2017). Thus, collaborations between initiatives spanning different ecological contexts could be a way to create synergies and integrations, translating project results and best practices from one context to another one (Loorbach *et al*., 2020). Equally, social collaborations between actors of LIFE-NAT projects which focus on different habitats could be a way to ensure functional connections among diverse socio-ecological contexts and better balance economic resource allocation to reduce the heterogeneous distribution of initiatives across EU habitats (Hermoso *et al.,* 2017).

### 4.3 Materials and Methods

Following previous experiences (*e.g*., Bodin *et al.,* 2019; Barnes *et al*., 2019; Bodin *et al*., 2016; Guerrero *et al.*, 2015), we ground the study on the SES theoretical concept, which is translated through the SEN approach, using stochastic Exponential Random Graph Modeling (ERGM) approaches (Lusher *et al*., 2013).

### 4.3.1 Data selection

This study focuses on LIFE-NAT projects co-founded by the LIFE Programme during its last programming period (2014-2020). In particular, as a case study, we analyze all LIFE-NAT projects acting at least in one N2000 site in Veneto, one of the 19 administrative regions located in the North-East of Italy (fig.4.1). We choose Veneto region because of its richness in LIFE-NAT projects initiatives and its ecological heterogeneity with marine, coastal, river, lowland, hillside, and mountain habitats (ISPRA, 2010). Veneto region is one of the most extensive regions in Italy, with a population of approximately 4.9 million people (8% of the Italian population) and a surface area of about 18.345 km² (6% of the Italian territory) (http://dati.istat.it/Index.aspx?DataSetCode=DCCV_CARGEOMOR_ST_COM). It is characterized by heterogeneities in the land morphology from high mountains in the North (e.g., Dolomites) covering 29% of the regional territory, flat land with the alluvial plain (i.e., Po Valley) which covers 57% of the regional area, and some hill areas covering 14% of the territory (https://www.reterurale.it/atlante/veneto/pdf/tabelle/ALT05_1_1.pdf) . Additionally, Veneto borders the Adriatic Sea for more than 150 km. Land use in the Veneto territory reflects socio-economic aspects characterizing the region, which is economically based on small-medium enterprises spread around the territory, especially in the plain where industry coexists with many small farms which typically adopt intensive agricultural practices to grow cereals, soybean, and horticulture. Conversely, the hill area is characterized by high-technological intensive viniculture to produce several famous wines whose landscape is recognized as immaterial patrimony by UNESCO (e.g., Prosecco hills). On the other hand, mountain areas are affected by limited access to services and reduced development opportunities which lead to depopulation trends, despite the high cultural and ecological value of traditional mountain landscapes (e.g., UNESCO Dolomites) and activities (e.g., livestock) (Zolin et al., 2019). Generally, despite the existence of portions of mountain areas characterized by naturalness, the Veneto region could be considered a region affected by multiple human stressors like pollution due especially to industrialization and urban sprawl, which is at the basis of the concept of “diffused town” (città diffusa) which characterizes urban settlements in the Veneto region (Staccione et al., 2022; Fregolent and Vettoretto, 2017). Nevertheless, the region is characterized by a complex arrangement of protected areas, with about 22% of the regional territory of protected areas composed of Natura 2000 sites and a National Park. Theses complex and diversified socio-economic and ecological features led to consider Veneto region a relevant area of analysis for the evaluation of the

governance of biodiversity which covers multiple tendencies characterizing EU territory (Trentanovi et al., 2018).

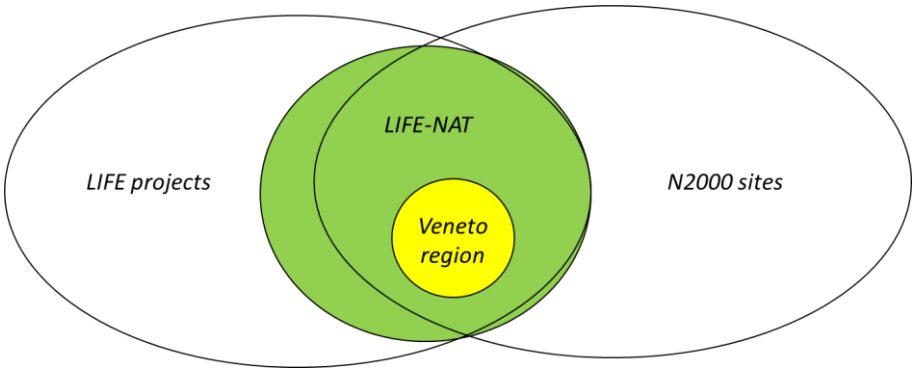



*Figure.4.1: LIFE-NAT projects selected in this study (in yellow). Source: own elaboration*

### 4.3.2 Methodological framework

Figure 4.2 shows how the SES concept (on the left of the figure) is operatively transposed in this study through the SEN approach. The social system in our analysis is represented by LIFE-NAT projects and LIFE-NAT projects' partnerships which are considered concrete examples of the environmental governance framework proposed by Lemos and Agrawal (2006), highlighting intersections between the State, the market, and the community. In this study, the ecological system refers to the N2000 sites located in the Veneto region and involved in selected LIFE-NAT projects, and protected habitats composing them.

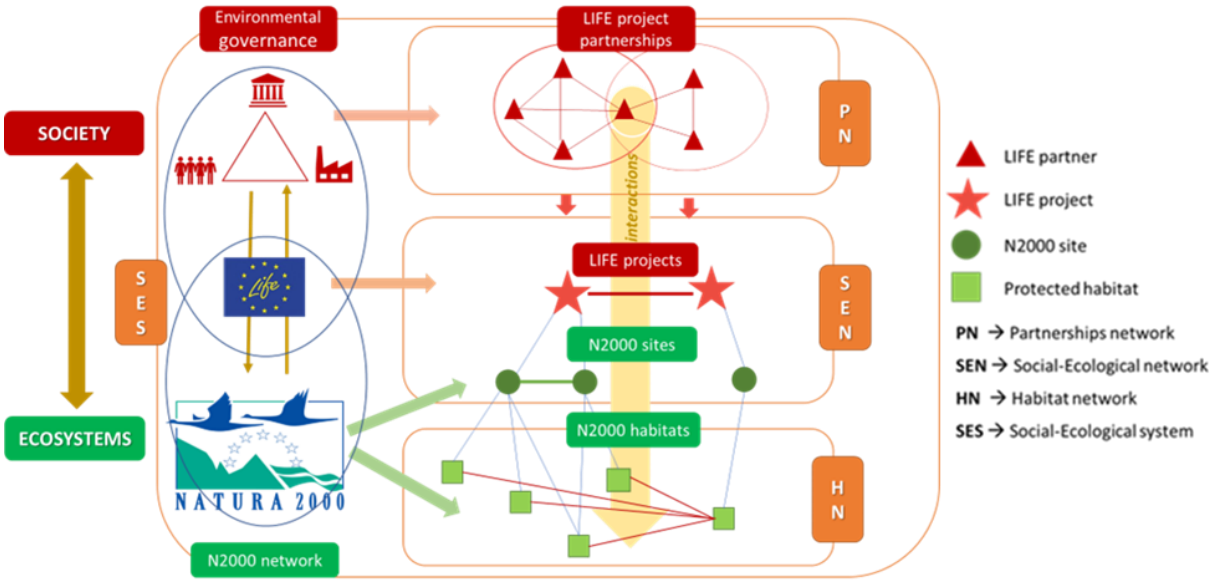



*Figure 4.2: Methodological framework of the study – Source: own elaboration*

We investigate social-ecological interactions presumably emphasized through the implementation of LIFE project activities through the analysis of three different networks, the Partnership Network (PN), the Social-Ecological Network (SEN), and the Habitat Network (HN), whose components are exposed in table 4.1.

| Network | Social Nodes | Ecological Nodes | Social-to-Social relations | Social-Ecological relations | Ecological-to-Ecological relations |
|---|---|---|---|---|---|
| **Partnership Network (PN)** | Project partners | - | Collaborations between actors, *i.e*. partners of the same LIFE-NAT project partnerships | - | - |
| **SEN** | LIFE projects | N2000 sites | Sharing of at least one partner in different LIFE-NAT projects | Implementation of LIFE-NAT projects activities in N2000 sites | Ecological connections through ecological corridors |
| **Habitat Network (HN)** | - | Protected habitats | - | Collaboration between different LIFE-NAT projects working in the same protected habitat | - |

*Table.4.1: Components of analyzed networks*

In the first network (Partnership Network - PN) in the upper part of figure 4.2) we focus on social-to-social relations through connections created via bottom-up activities of intermediary actors (*i.e.,* brokers), as already analyzed by Pisani *et al*. (2020) and Rigo *et al.* (2022). In this study, relationships between LIFE-NAT project partners refer specifically to the mutual collaborative relations among actors sharing environmental responsibility for biodiversity conservation through the proposal and implementation of a LIFE-NAT project in an N2000 site. We assume that such relationships are based on reciprocal communication about interventions implemented by every partner and the exchange of knowledge to identify best available practices and foster adaptive learning within the network (Munck af Rosenschöld and Vihma, 2022; Andriollo *et al*., 2021; Gavin *et al*., 2018).

The second and third networks overcome the purely social-focused analysis and shift the attention towards the social-ecological relationships that emerged through the implementation of LIFE-NAT projects, taking both social and ecological connectivity into account. In particular, the second network -represented in the

central part of figure 4.2- aims to visualize a fully articulated Social-Ecological Network - SEN) (Sayles *et al.,* 2019), showing connections between and within LIFE-NAT projects and N2000 sites.

The third network, (Habitat Network - HN, at the bottom of figure 4.2), deepens social-ecological interactions fostered by social collaborations stimulated by LIFE-NAT projects. The network aims to highlight how social collaborations connect multiple and different protected habitats that compose N2000 sites. Here the network is weighted, with relations having different values due to the numerosity of collaborations between LIFE-NAT projects insisting on the same N2000 site (Krivitsky, 2012).

### 4.3.3 Data extraction and database creation

Information related to LIFE projects and actors is available on the LIFE Programme website since 1992. For this study, we extract information concerning beneficiaries composing LIFE-NAT partnerships and N2000 sites in the target Italian region (Veneto). After then, we add other relevant information about them extracted by consulting another source of data, *i.e.,* the N2000 database provided by the European Environment Agency. In particular, we extracted information about protected habitat types composing the selected N2000 sites. Additionally, through the consultation of the Veneto region PTRC (Piano Territoriale Regionale di Coordinamento), we retrieve information on ecological corridors able to connect N2000 sites.

After the data extraction, we classify all nodes distinguishing social and ecological nodes. Additionally, for every social actor, we specify its jurisdictional level distinguishing international, national, regional, and local levels (Cash *et al.,* 2006), and the typology of actors following the classification proposed by Lemos and Agrawall (2006) distinguishing public authorities (the State), NGOs (the community), and private bodies (the market), adding two more categories: University/Research centers (the third sector, see Avelino and Wittmayer, 2015) and Parks because of their important role in the management of protected areas. Additionally, we classify habitats following EUNIS classification, distinguishing marine habitats, coastal habitats, freshwater habitats, heaths and scrubs habitats, grassland habitats, bogs, mires, fens habitats, rocky habitats and forest habitats. Consequently, we created a new database with information related to selected LIFE-NAT projects ("Projects section"), every beneficiary composing each project's partnerships ("Beneficiaries section"), every N2000 site involved in projects ("N2000 section"), and every protected habitat composing the N2000 site ("Habitat section").

Information that is not reported in the previously cited sources, like the typology and scale of actors and the habitat classification, is retrieved through partners' websites (for the identification of type and level) and in the EUNIS (European Union Nature Information System) website.

#### 4.3.4 SEN statistical analysis

Networks are typically analyzed through Social Network Analysis (SNA) which studies relations among multiple nodes defined by edges constituting the analyzed network (Borgatti *et al.,* 2013). In our case, this method can help identify structures and relational patterns between entities represented by nodes, highlighting recommendations helpful in improving the effectiveness of environmental interventions related to the social-ecological fit (*e.g.,* Bodin and Tengo, 2012).

Relationships are analyzed through different approaches due to the nature of ties composing networks. For the specific case of social-ecological relationships, we use single-layer (*i.e*., allows only one single type of tie in the network) and multilevel (*i.e.,* enables multiple kinds and quantities of edges within and between layers) approaches (Sayles *et al.,* 2019). In particular, the PN and HN single-layer networks. Conversely, the SEN is a multilevel network.

From a statistical perspective, it is essential to highlight that one of the main implications in network analysis is the irrationality of assuming independence between ties composing networks, so it is not possible to use standard statistical methods that assume independence among explanatory variables of the model (Lusher *et al.,* 2013). To solve these problems, Exponential Random Graph Models (ERGM) is one of the most important families of models proposed to statistically develop sound network analyses, which is also suitable for multilevel networks (Lusher *et al.,* 2013; Wang *et al.,* 2013).

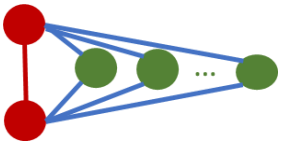
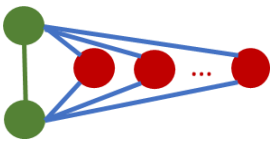
##### 4.3.4.1 ERGM

ERGMs are the principal approach used to model networks. They consider the presence or absence of network ties from which structural configurations emerge, reflecting behaviors or tendencies of the system we are analyzing (Lusher *et al*., 2013). As with every statistical model, ERGMs can make inferences about patterns characterizing the analyzed network, indicating if there are more or fewer observed structures in the network than expected by chance (Lusher *et al*., 2013; Wang *et al*., 2013). In other words, models can verify the presence or absence of tendencies in making relationships by analyzing sub-graph configurations

in the studied network. Specifically, ERGMs can infer if a specific network configuration is significantly more present or absent than expected, comparing the observed network with all its possible rearrangements (Lusher *et al*., 2013). For example, suppose a protected area is managed by actors who collaborate. In that case, ERGMs show the tendency of triadic closure between two social nodes and one ecological node, as detected by Bodin *et al.* (2016). Additionally, ERGMs allow for the analysis of covariates to deepen the analysis, considering not only the endogenous structure but also exogenous patterns determined by the specific characteristics of nodes, *e.g.,* attributes that classify nodes composing the network (Lusher *et al.,* 2013).

#### 4.3.4.2 Network statistics

To verify research hypotheses reported in table 4.2, we rely on multiple network statistics (tab.4.3) composing ERGM models used in this study to analyze PN, SEN, and HN.

| Hypothesis | Configuration |
|---|---|
| **H1**<br>**LIFE-NAT projects promote social collaborations between partners able to concretize multilevel and multi-actor governance** |  |
| **H2**<br>**A specific N2000 site represents a well-defined contextual setting for multiple collaborations determined by multiple LIFE-NAT projects.** |  |
| **H3**<br>**LIFE-NAT projects act mainly in N2000 sites that are ecologically connected through ecological corridors.** |  |
| **H4**<br>**LIFE-NAT projects stimulate synergic social collaborations among actors and initiatives that implement actions across different habitats.** |  |

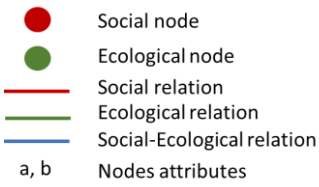



*Table.4.2: Network configurations representing research hypotheses of this study*

| Hypothesis | Network statistics | Measure | Statistical Estimation |
|---|---|---|---|
| H1 | **Edges** | Number of edges in the network | Density of the connections in the network |
| H1 | **Nodematch_level** | Number of edges between two nodes characterized by the same level | “Uniform homophily" in the network for "level" attribute |
| H1 | **Nodematch_type** | Number of edges between two nodes characterized by the same typology of actor | “Uniform homophily" in the network for "types" attribute |
| H1 | **Gwdegree** | Number of edges for every node | Degree distribution in the network |
| H2, H3 | **AEdge** | Number of edges within social nodes | Density of social relations |
| H2, H3 | **BEdge** | Number of edges within ecological nodes | Density of ecological relations |
| H2, H3 | **XEdge** | Number of edges between a social and an ecological node | Density of social-ecological relations |
| H2 | **ATXAX** | Number of connected social dyads which share multiple ecological nodes | Triadic closure between two social nodes connected to the same ecological nodes |
| H3 | **ATXBX** | Number of connected ecological dyads which share multiple social nodes | Triadic closure between two ecological nodes connected to the same social nodes |
| H4 | **Sum** | Sum of the values of all the relations composing the network | Density of the network |
| H4 | **Nodematch.sum.HABITAT, diff=TRUE** | Sum of values of ties between nodes having the same attribute | “Differential homophily" in the network, distinguishing tendencies of homophilic interactions for every habitat class |
| H4 | **Transitiveweights.min.max.min** | Sum of values of ties which share multiple nodes in the network | Tendencies of nodes to create triadic closures in the network, meaning that two nodes tend to be connected because they share multiple other nodes. |

*Table.4.3: Network statistics used in this study*

We verify the presence or absence of multi-actor and multilevel collaborations in LIFE-NAT projects (H1) by analyzing LIFE-NAT partnerships represented through the PN. We make an ERGM model composed of the network statistics: "*Edges*", "*Nodematch_level*", "*Nodematch_type*", "*Gwdegree*", reported in tab.4.3 (Krivitsky *et al*., 2021). Then, we create an ERGM model helpful to address H2 and H3 through the study of endogenous network statistics verifying the presence or absence of structural configurations (Wang *et al*., 2013). The model is composed of the following network statistics reported in tab.4.3: "*AEdges*", "*BEdges*", "*XEdges*", "*ATXAX*", "*ATXBX*". Specifically, for H2 purposes, we use the *ATXAX* statistic, and for H3 purposes, the *ATXBX* statistic (table 4.2). Finally, we verify the presence of synergic social collaborations between projects acting across different habitats (H4) through the HN, creating an ERGM-weighted model (Krivitsky, 2012) composed of network statistics: "Sum", "Nodematch.sum.habitat" and "Transitiveweights.min.max.min" (tab.4.3).

## 4.4 Results

According to the selection criteria applied in this study, we identify: (i) 13 LIFE-NAT projects, (ii) 83 social actors composing partnerships, (iii) 29 N2000 sites, and (iv) 57 protected habitats.

### *4.4.1 PN network*

*H1: LIFE-NAT projects promote social collaborations between partners able to concretize multilevel and multi-actor governance.*

*R1: a sparse PN network characterized by homophilic relations*

The PN, shown in figure 4.3, comprises 83 nodes representing all actors involved in LIFE-NAT project partnerships. The network is composed of 24 universities/research centers, 22 public authorities, 14 parks, 13 private bodies, and 9 NGOs. Such actors operate at international, national, regional, and local jurisdictional levels, as shown by 2, 32, 29, and 19 nodes. Universities/research centers and public bodies, including parks, are the most recurrent types of partnership actors, representing 73% of the total nodes constituting PN, demonstrating the fundamental role of public authorities in LIFE-NAT projects partnerships, counterposed to the low involvement of NGOs and private bodies. Similarly, national or regional levels represent the most frequent jurisdictional levels composing LIFE-NAT partnerships representing 74% of the total nodes in the network. Additionally, through figure 4.3, it is possible to identify three actors making the role of gatekeepers

(*i.e.,* central actors able to influence the resource and information flow across the network) connecting multiple partnerships: two universities and one regional authority.

The negative value for both *edges* and *gwdegree* network statistics (tab.4.4) demonstrate low density in the network and the absence of variability in the degree of nodes, meaning the presence of a sparse network without popular nodes composing LIFE-NAT partnerships. On the other hand, the positive value of *nodematch* network statistics for both the level and type of actors show high densities in relationships within the same group of actors, verifying the tendency to make homophilic relationships in the network. The model has been tested to verify its stability and goodness of fit.

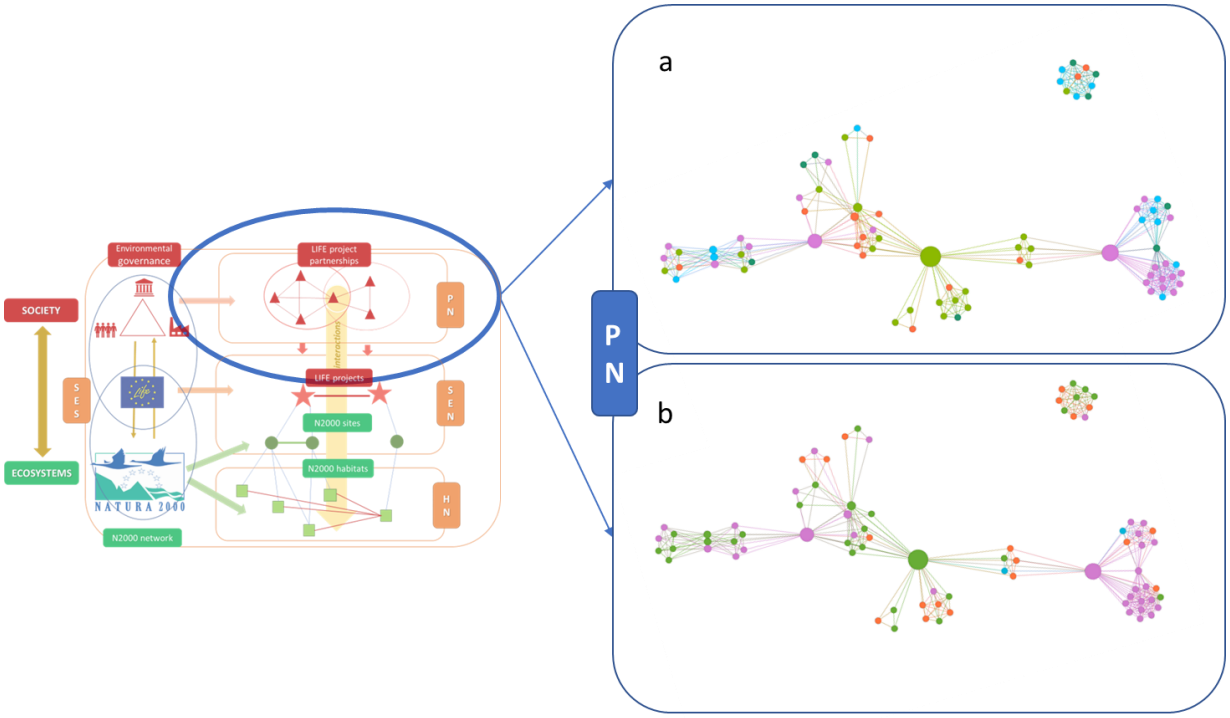



*Figure 4.3: (a) PN with colors representing the typologies of actors: violet= universities/research centres, green=public authorities, blue= parks, orange= private bodies, dark green=ONG, (b) with colours representing the jurisdictional scale: green=regional, violet=national, orange=local, blue=international*

| | **Estimate** | **Std.** | **P value** |
|---|---|---|---|
| **edges** | -2.43197 | 0.08402 | P < 0.0001 |
| **nodematch.level** | 0.65215 | 0.11185 | P < 0.0001 |

| | | | |
|---|---|---|---|
| **nodematch.type** | 0.81640 | 0.11758 | P < 0.0001 |
| **gwdeg.fixed.0.7** | -2.54820 | 0.65737 | P < 0.0001 |

*Table.4.4: ERGM results for Partnership Network.*

### 4.4.2 SEN network

*H2: A specific N2000 site represents a well-defined contextual setting for multiple collaborations determined by multiple LIFE-NAT projects.*

*H3: LIFE-NAT projects act mainly in N2000 sites that are ecologically connected through ecological corridors.*

*R2: The non significant value of network statistic does not allow us to verify the hypothesis.*

*R3: LIFE-NAT projects tend to act in N2000 sites connected through ecological corridors.*

The SEN (fig.4.4) comprises 13 LIFE-NAT projects and 29 N2000 sites. It shows that all LIFE-NAT projects are connected through social-to-social ties except for one. Additionally, fig.4.4 shows that most of the N2000 sites where LIFE-NAT projects intervene are connected through ecological-to-ecological connections. Finally, the figure shows that 24% of N2000 sites are involved in more than one LIFE-NAT project and, equally, 61% of LIFE-NAT projects act in more than one N2000 site placed in Veneto Region.

Results of the multilevel ERGM model are reported in table 4.5. In addition, the model has been tested to verify its stability and goodness of fit.

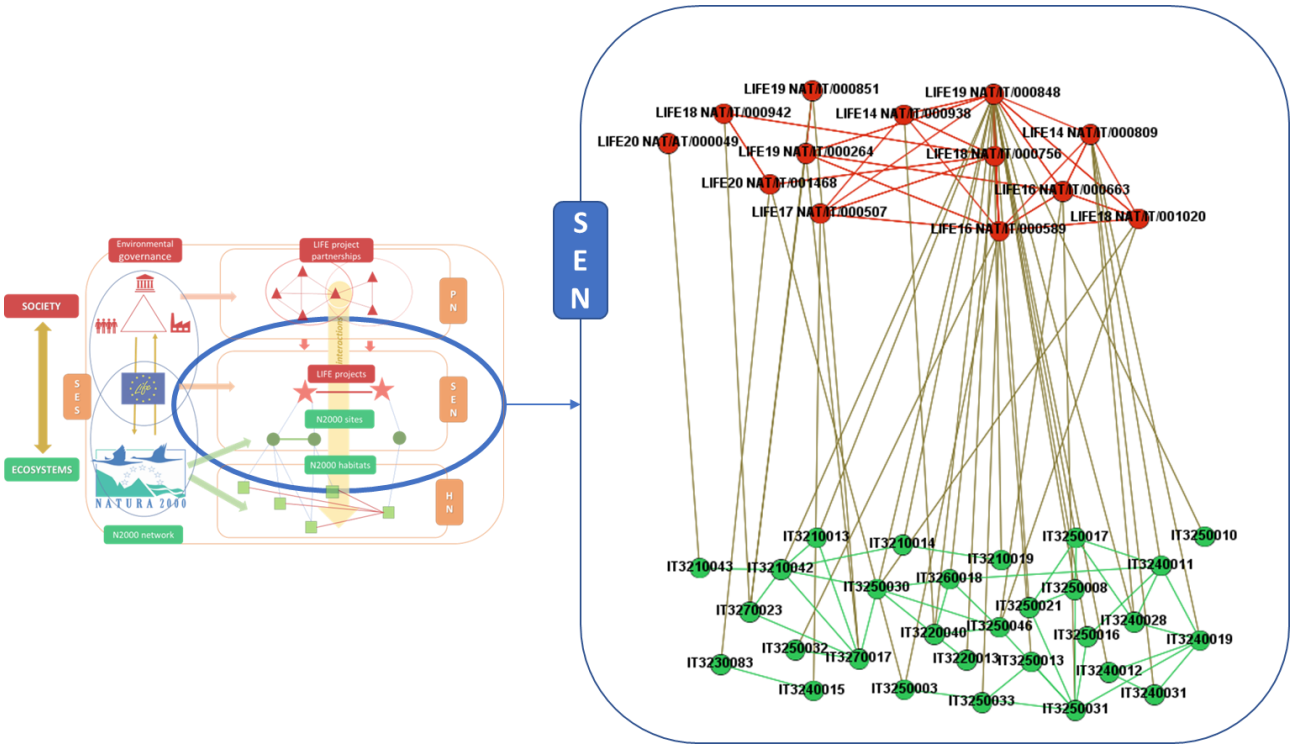



*Figure 4.4: SEN representation*

| | Estimate | Std. | P value |
|---|---|---|---|
| **AEdge** | -0.66441 | 0.256978 | P < 0.05 |
| **BEdge** | -2.60494 | 0.219204 | P < 0.0001 |
| **XEdge** | -2.75755 | 0.229168 | P < 0.0001 |
| **ATXAX** | -0.14911 | 0.435848 | n.s. |
| **ATXBX** | 1.34461 | 0.165305 | P < 0.0001 |

*Table.4.5: ERGM results for SEN*

The negative values of *AEdge, BEdge*, and *XEdge* network statistics indicate that the network is characterized by low values of densities for all types of edges composing the SEN, meaning a sparse network. The results of *ATXAX* network statistics that we used to verify H3 are non-significant. This implies that verifying H4 is impossible. Practically, the model cannot detect if triadic closures are significantly more or fewer than a random graph. Conversely, the significant and positive value of the network statistics *ATXBX*, used to verify H3, demonstrates the presence of triadic closures between couples of ecological nodes which share social nodes, showing that selected LIFE-NAT projects tend to act in N2000 sites connected through ecological corridors.

### 4.4.3 HN network

*H4: LIFE-NAT projects stimulate synergic social collaborations among initiatives that implement actions across different habitats.*

*R4: Marine and coastal areas foster homophilic relationships. Conversely, forest habitats foster heterophilic relationships.*

The HN is constituted of 57 nodes representing different types of protected habitats, specifically, 9 marine habitats, 7 coastal habitats, 8 freshwater habitats, 2 heaths and scrubs habitats, 9 grassland habitats, 3 bogs, mires, fens habitats, 3 rocky habitats and 16 forest habitats. Figure 4.5 identifies a set of central habitats in the center of the network composed of 24 nodes, specifically, 9 marine habitats, 6 coastal habitats, 4 freshwater habitats, 3 forest habitats and 1 grassland habitat. Then, a reduced set of other habitats, especially grassland and river habitats, create a peripheral cluster in the network, composed of 9 nodes. Finally, all the other habitats (24 nodes) are placed in the periphery of the network, with edges having a low weight.

To verify H4, the estimated positive values reported in table 4.6 related to *nodematch.sum* network statistics show high densities of ties between the first two habitat classes, meaning the tendency to make homophilic interactions between LIFE-NAT projects focused on sea areas (habitats classes 1 and 2). Conversely, the significant negative value for habitat class 9, representing forest habitats, indicates the tendency to make relations between different types of habitats when forests are involved. Non-significant values for freshwater and grassland habitats (habitat classes 3 and 6) do not allow the demonstration of their tendency to make heterophilic relations. Therefore, we avoid reporting other habitat classes because they have null values of internal density. Consequently, from a statistical point of view, it is impossible to understand their tendencies to create relationships with other habitats. Additionally, the high value of *transitive.weight* network statistic reveals the presence of transitivity in the network, that is, the presence of triangles composed of three ecological nodes, which concretely highlights that collaborating LIFE projects share multiple habitats. Finally, the model has been tested to verify its stability and goodness of fit.

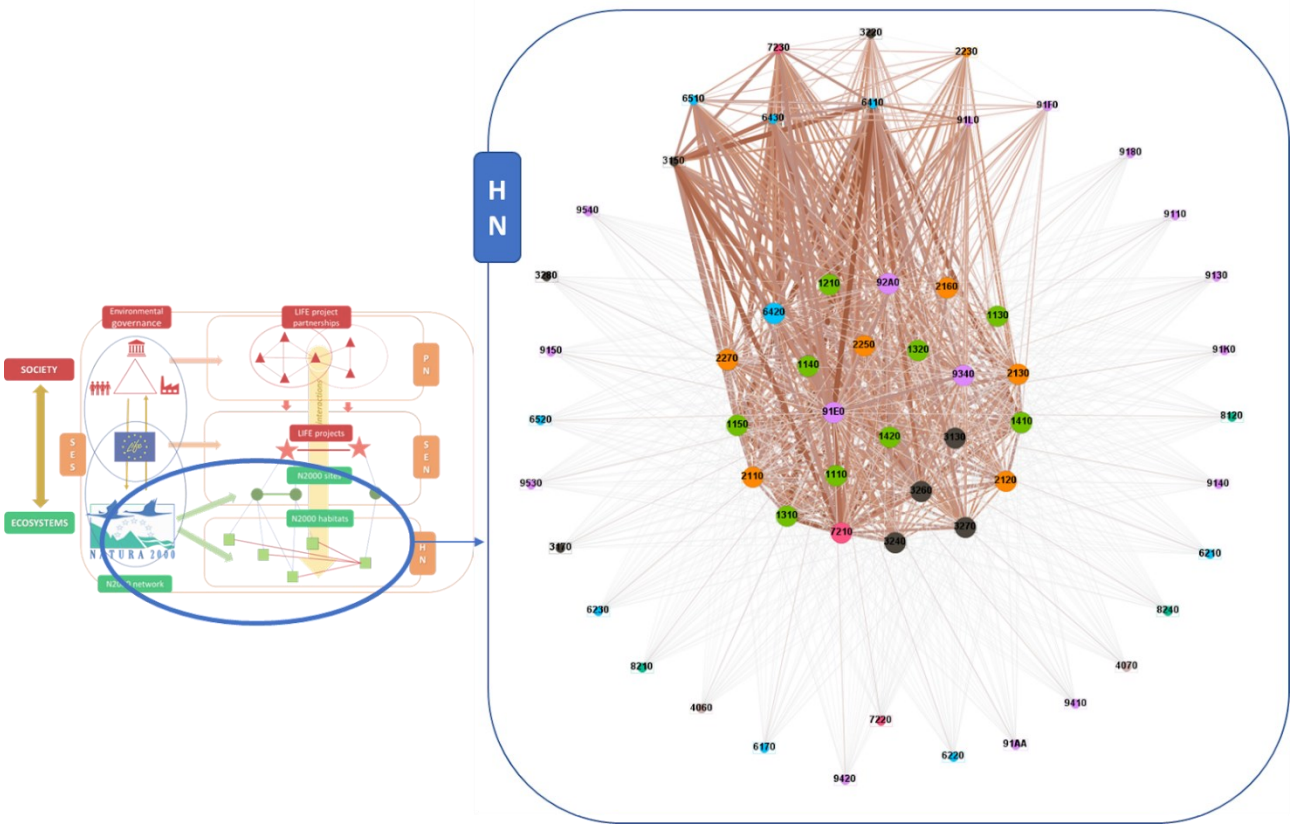



*Figure 4.5: HN graphical representation. Nodes are coloured according to the EUNIS classification (green= marine habitats, orange= coastal habitat, black= freshwater habitats, brown= heat and scrubs habitats, blue= grassland habitats, pink= bogs, mires, fens habitats, aquamarine= rocky habitats, violet= forest habitats).*

| | **Estimate** | **Std.** | **P value** |
|---|---|---|---|
| **sum** | -1.53706 | 0.20651 | P < 0.0001 |
| **nodematch.sum.HABITAT1.1** | 2.78910 | 0.38325 | P < 0.0001 |
| **nodematch.sum.HABITAT1.2** | 0.96424 | 0.23074 | P < 0.0001 |
| **nodematch.sum.HABITAT1.3** | -0.09563 | 0.23548 | n.s. |
| **nodematch.sum.HABITAT1.6** | -0.25100 | 0.21362 | n.s. |
| **nodematch.sum.HABITAT1.9** | -1.34725 | 0.16259 | P < 0.0001 |
| **transitiveweights.min.max.min** | 1.13206 | 0.20683 | P < 0.0001 |

*Table.4.6: ERGM results for HN*

### 4.5 Discussion

In this section, results are discussed following research hypotheses at the basis of this study. After the discussion of results, the last paragraph clarifies the strengths, limitations and future applications of the methodology proposed by this study. Firstly, we want to highlight that this study is focused on LIFE-NAT projects in Veneto region. Thus, the results that emerged from the analysis do not represent all EU contexts where LIFE-NAT projects are implemented, nor Italy's national context.

#### 4.5.1 LIFE-NAT projects and stakeholders

*H1: LIFE-NAT projects promote social collaborations between partners able to concretize multilevel and multi-actor governance.*

*D1: LIFE-NAT projects promote a polycentric governance but fail in fostering a multi-level and multi-actor governance.*

The sparse network constituted by LIFE-NAT project partnerships implies that LIFE-NAT projects in Veneto region create a polycentric governance system where biodiversity conservation activities are implemented by different and multiple actors who are potentially interdependent in various and complex ways stimulating CEG through bottom-up initiatives (Heikkila *et al.,* 2018; Bodin *et al*., 2017). Results are in line with what is reported in the scientific literature concerning the LIFE Programme governance and with the EU legal framework promoting and sustaining participatory approaches into the top-down mechanisms constituting the EU multilevel governance (*e.g.,* Rigo *et al.,* 2022; Gargano, 2021; Pisani *et al.,* 2020; Newig and Koontz, 2014). Nevertheless, the tendency to make homophilic relations across partners implies the failure of LIFE projects in fostering multilevel and multi-actor governance, as H1 attests the prevalent presence of homophilic relations between public authorities in LIFE-NAT partnerships that already have the jurisdictional responsibility of managing and protecting protected areas (Lai, 2020), and the consequent marginal role of NGOs and private bodies, implies a reduced inclusion of local stakeholders. These tendencies probably reduce the effectiveness of CEG activities like LIFE-NAT projects, limiting the increase of shared environmental responsibility (Andriollo *et al.,* 2021; Campbell-Arvai, 2019; Widman, 2015; Evans *et al*., 2008). In particular, if LIFE-NAT projects involve multiple and different locals in their partnerships, they would increase the legitimation of activities and, consequently, the prevention or resolution of conflicts, the support

of project initiatives from the community, and the prosecution of conservative actions even after the end of the project (Munck af Rosenschöld and Vihma, 2022; Staniscia *et al.,* 2019). Additionally, participation increases public opinion about biodiversity loss challenges, their repercussions in our everyday life, and the importance of adopting a sustainable lifestyle (Ardoin *et al.,* 2020; Peter *et al*., 2019). In this way, it is possible to foster sustainable transformations required to achieve sustainable development goals, which require local interventions to stimulate global changes (Moczek *et al*., 2021; Loorbach *et al.,* 2020; Folke *et al*., 2016). Additionally, if locals are proactive parts of the LIFE-NAT project, or generally, in the management of N2000 sites, their awareness about EU efforts to face biodiversity degradation is expected to increase, also enhancing their truth in public authorities, which at present, in Italy, is low (Tonin and Lucaroni, 2017). Not surprisingly, public awareness of N2000 existence and conservation objectives in Italy, and generally, in all EU territories, is reduced, limiting the successes of the N2000 initiative because awareness is a precondition for a winning conservation policy (Kokkoris *et al.,* 2023).

### 4.5.2 LIFE-NAT projects and N2000 sites

*H2: A specific N2000 site represents a well-defined contextual setting for multiple collaborations determined by multiple LIFE-NAT projects.*

*D2: Multiple LIFE-NAT projects act in the same Natura 2000 site. Simultaneous projects allow to tackle the whole range of conservation problems through different tools, allowing to by-pass the possible limit of too much circumscribed specific objectives.*

The non-significant value of ATXAX network statistic in SEN does not allow for verification of H2. Nevertheless, SEN highlights the presence of many N2000 sites involved in more than one LIFE-NAT project, indicating that LIFE projects represent opportunities to foster ecological interventions, but they could not exhaustively face the entire conservation challenges of a specific N2000 site (Munck af Rosenschöld and Vihma, 2022; Hermoso *et al*., 2017) because projects are limited through specific objectives which focus on particular species or habitats. This is why it is possible to identify more than one LIFE-NAT project simultaneously acting in the same N2000. Therefore, we want to highlight the importance of establishing collaborations between LIFE-NAT projects, which can overcome the intrinsic limitations of projects creating synergies between interventions focused on the same area, integrating conservation objectives in different

periods, and, thus, expanding interventions scopes and durations, as required by the needed long-term and holistic conservation approaches (Munck af Rosenschöld and Vihma, 2022; Hermoso *et al*., 2022; Holzer *et al.*, 2019; Peña *et al.,* 2017).

### 4.5.3 LIFE-NAT projects and ecological connectivity

*H3: LIFE-NAT projects act mainly in N2000 sites that are ecologically connected through ecological corridors.*

*D3: LIFE-NAT projects' tendency to act in connected N2000 sites demonstrates advances of the LIFE Programme in managing the N2000 network.*

The positive value of ATXBX network statistics verifies H3, evidencing that LIFE-NAT projects can support the ecological connectivity of protected areas (Martini *et al.,* 2017; Bodin, 2017). This result makes evidence of advances fostered by the LIFE Programme in the governance of the N2000 network, which needs to increase coordinated activities between connected N2000 sites spanning the EU territory (Hermoso *et al*., 2022). Only in this way, the N2000 initiative could concretize its network nature which gives itself an added value compared with other conservation initiatives like the institution of isolated natural parks (Campagnaro *et al*., 2019; Martini *et al*., 2017; Ferranti *et al*., 2010). In this study, valorizing ecological connectivity is even more important because most of the selected LIFE-NAT projects act in the Padan Plain, which is particularly disturbed and modified by human activities. Padan Plain is one of the most polluted areas in Europe, characterized by high fragmentation of ecological patches, where protected areas represent only a small portion of territory but are fundamental for the protection of multiple endangered species (Staccione *et al*., 2022). Additionally, they play an essential role in the social well-being of the local community, offering quiet and natural places inside an urbanized territory, fostering tourism and relaxing experiences (Jones *et al*., 2020; Jiricka-Pürrer *et al*., 2019; Schirpke *et al*., 2018). Previous experiences reported in the literature, like Martini *et al.* (2017), demonstrate the fundamental role of ecological connectivity across N2000 sites to ensure social and economic outcomes. From a social perspective, promoting coordinated and coherent governance of multiple N2000 sites stimulates traditional and sustainable economic activities and public participation in a wide area (Martini *et al.,* 2017). From an ecological perspective, coordinated management of connected, protected areas is the only way to sustain species that need to move and simultaneously

ensure well-managed N2000 sites able to provide resources and shelters to species (Hermoso *et al.,* 2022; Saura *et al*., 2018; Hermoso *et al*., 2017).

### 4.5.4 LIFE-NAT projects and habitat synergies

*H4: LIFE-NAT projects stimulate synergic social collaborations among actors and initiatives that implement actions across different habitats.*

*D4: LIFE-NAT projects establish collaborations able to foster synergies across marine, land and freshwater ecosystems promoted by the transversal role of forests.*

The composition of HN reveals that LIFE-NAT projects implemented in Veneto region concern both land and sea habitats. Specifically, marine and coastal habitats located in the Venice Lagoon and Po Delta represent most of the nodes located in the central position of HN. This result implies that the sea environment better stimulates the emergence of collaborations between LIFE-NAT projects implemented in the Veneto region, in contrast to general EU tendencies, which generally focus on land habitats (EEA, 2020; Hermoso *et al.,* 2017). Conversely, the peripheral position of most land habitats refers to the absence of collaboration between multiple LIFE-NAT projects in the continental area of the Region, except for a peripheral cluster, composed especially of grassland and freshwater habitats which refer to protected areas placed across the Padan Plain. Generally, as detected by *transitive.weight*, LIFE-NAT projects are more incentivized to collaborate when they share similar habitats, challenges, and needs. In this way, collaborations between projects could be opportunities to concretize adaptive governance, improving conservation approaches through a learning-by-doing process (Andriollo *et al*., 2021; Folke *et al*., 2005). Results identify coastal and estuaries as core areas where conservation efforts are fostered through collaboration between LIFE-NAT projects. Specifically, through *nodematch.sum* network statistics, the analysis highlights the bridging role of forests, revealing that selected LIFE-NAT projects stimulate synergies between different habitats when they involve forest habitats. Conversely, LIFE-NAT projects focused on the sea tend to collaborate only if they concern marine or coastal habitats. Such results could be explained by the localizations of most of the LIFE-NAT projects which collaborate, Venice Lagoon and Po Delta. They represent focal areas of land-sea interactions where multiple biological, geochemical, and social processes are strictly intertwined (Fang *et al.*, 2017). This evidence shows the capacity of selected LIFE-NAT projects to establish collaborations able to

foster synergies across marine, land and freshwater ecosystems promoted by the transversal role of forests. Additionally, such areas also have a cultural and historical value for the regional population to be preserved, facing new challenges related to sustainability achievement (Day *et al.,* 2019). In particular, the city of Venice, which has been nominated as a UNESCO world heritage, needs to face climate change challenges that are more visible than normal (Umgiesser, 2020; Cavalieri *et al*., 2019). Additionally, the lagoon is generally recognized as an important area for protecting biodiversity frightened by industrialization and petrochemical pollution due to human activities surrounding it, revealing that collaborative efforts for biodiversity are fostered where human pressures are more perceived. (D'Alpaos and D'Alpaos, 2021; Scarpa *et al.,* 2019; Zonta *et al.,* 2007).

### 4.5.5 Strengths, limitations, and future application of the methodology proposed by this study

This study applies a statistically sound methodology (Lusher *et al.,* 2013) to evaluate the effectiveness of EU LIFE-NAT projects. In this sense, it proposes a novel approach that gives robustness to the network analysis (Sayles *et al*., 2019; Bodin *et al.,* 2019; Bodin *et al.,* 2016). To test the application of such a robust statistical approach to network analysis, we used a regional case study. Nevertheless, the proposed methodology could be used to verify the effectiveness of environmental activities in national and EU contexts, thus getting a complete overview and detailed picture of tendencies in the CEG sustained by the EU LIFE Programme. The same type of analysis could be replicated in all EU contexts because the data used by this study are open-source and available for all EU countries through EU open databases. The only data retrieved from a regional source concern ecological corridors, but, at present, such information is quite explored by the scientific literature, which offers methodologies able to detect ecological corridors if they are not shown by territorial plans, like Popescu *et al.* (2022). Nevertheless, the methodology has some limitations. For example, it cannot be used to systematically analyze other typologies of LIFE projects because the LIFE Programme database does not give information about their localization. Only for LIFE-NAT projects are specified in which N2000 sites the projects act. The lack of clear and standardized data about the typologies of actors and their jurisdictional level in the LIFE Programme database implies a classification made by researchers which could be considered arbitrary. In addition, the LIFE Programme does not give information about other stakeholders outside the LIFE project partnership, *e.g.,* co-financier (Rigo *et al*., 2022). So, the analysis may not detect some important actors involved in LIFE projects. Additionally, focusing on the methodological approach used

in this study, we faced multiple data analysis problems because of the reduced availability of analytical tools suited to analyze multilevel networks (see also Guerrero *et al*., 2015).

Thus, we identify many further progresses that are required to consolidate and expand the SEN research area and produce scientific results that can be useful for policymakers. Firstly, from a statistical point of view, there is a need to improve multidisciplinary collaborations between statistic model developers and applied researchers to develop new tools to model multilevel networks representing SES. Secondly, focusing on the specific case of LIFE Programme evaluation, further studies could explore social-ecological relationships supported by LIFE-NAT projects focusing on other Italian regions or various national contexts to compare different EU territories characterized by differences in legal frameworks, cultures, ecosystems, and perceptions. More generally, further studies could apply this framework in the whole EU context giving a general picture of tendencies in the LIFE governance in Europe. This could be useful to indicate how to improve future EU environmental policies and allocations of resources to foster participation and collaborations. Additionally, this methodology could be applied to other periods to analyze the evolution of the conservation efforts supported by the LIFE Programme during the 30 years of its life to detect errors and successes of the EU conservation policy over years using a learning-by-doing perspective.

**4.6 Conclusions**

The innovative approach proposed by this study to evaluate the effectiveness of CEG from a network perspective allows identifying advances and limitations of CEG for biodiversity conservation and restoration supported by LIFE-NAT projects implemented in the Veneto region in the 2014-2020 period.

From the analysis of network structures, it is possible to obtain recommendations that could be helpful for policymakers and practitioners to enhance the composition of project partnerships and to identify suitable objectives and intervention areas. PN highlights the need for increased heterogeneity in LIFE project partnerships through the active involvement of market and not-for-profit organizations, acting especially at a local jurisdictional level. The importance of participative processes for biodiversity needs to be clarified and fostered, especially at subnational levels (*i.e.,* regionally and locally). Empowering local communities through communication (*e.g*., sensibility campaigns) and education (*e.g*., EU project management courses) is fundamental to achieving effectiveness in CEG. In future LIFE-NAT partnerships, such new actors need to be

sustained by the transversal presence of bridging actors already included in current projects to favor a learning-by-doing process. This is why it is essential to favor the stable presence of central actors in the governance of N2000 sites because they can ensure coherent and integrative governance of the N2000 network based on adaptive governance principles, thus determining larger and better integrated positive environmental outcomes.

The analysis demonstrates the capacity of the selected LIFE-NAT projects to valorize the ecological connectivity of protected areas and to sustain land-sea interactions through the bridging role of forest habitats. Therefore, future LIFE-NAT projects must continue to consider ecological connectivity and synergies across marine, freshwater, and land habitats in future initiatives. In this way, they can favor coordination and coherence in the CEG of protected areas spanning the EU territory. Furthermore, the approach proposed by this study could help identify hidden social-ecological relationships affecting the social-ecological fit of CEG initiatives that traditional methodologies like remote sensing could not trace. For example, integrating network analysis through SEN to other evaluation methodologies could help identify new objectives in the conservation of fundamental species or habitats or different natural areas which need to be protected in order to enhance the effectiveness of conservation efforts concretizing a transversal, holistic and coherent CEG of protected areas.

**Author Contributions**

Conceptualization, E.A., E.P. and A.C.; methodology, E.A. and A.C.; data curation, E.A.; writing—original draft preparation, E.A.; writing—review and editing, E.A., L.S., E.P.; A.C. supervision, E.P., L.S., and A.C. All authors have read and agreed to the published version of the manuscript.

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None.

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# Chapter 5: Concluding remarks and recommendations.

The present chapter aims to resume critical concepts and results obtained during these three years of research. Specifically, it is subdivided into three paragraphs. The first paragraph presents the evolution of the study and the integration of theoretical concepts and frameworks to clearly analyze social-ecological relationships that emerged from the LIFE projects implementation. Therefore, it clarifies the relevance of papers and their contribution to scientific knowledge on evaluating collaborative environmental governance. Then, the second paragraph highlights study limitations, proposing future developments in this research area. Finally, the third paragraph concludes with policy recommendations derived from the analysis of papers composing the dissertation to clearly indicate to policymakers and practitioners how to stimulate effective collaborative efforts that consider interdependencies within and between society and natural ecosystems.

## 5.1 Theoretical contribution

This dissertation focuses on interdependencies between society and natural ecosystems to understand how social efforts could effectively address environmental challenges.

The literature review (**Article 1**) shows that environmental challenges to be effectively faced need to consider social and ecological peculiarities affecting the problem to catalyze sustainability transformations. Theoretical implications derived from such a concept strengthen the adaptive governance framework characterized by the fundamental role of adaptivity, integration, and collaboration. Therefore Article 1 summarizes adaptive governance principles proposing a framework that adopts a perspective specifically focused on environmental interventions to highlight how social transformations can positively or negatively impact natural ecosystems. Results of Article 1 identify multiple recommendations from the evaluation of past experiences using a learning-by-doing perspective, setting a background for future design, implementation, and evaluation of environmental activities based on adaptive governance of SES.

Specifically, the study clarifies the fundamental role of ***community participation in governance activities*** to foster community awareness about environmental challenges and their role in facing them and, consequently, stimulate a shared environmental responsibility. Specifically, the community is seen as an active part of the political and scientific discussion with its own knowledge and experiences, which need to be considered relevant as scientific and policymakers' perspectives, becoming co-creator of new valuable

knowledge for new strategic governance processes. Operatively, the literature review extracts practical ways to concretize an effective collaborative adaptive governance. In particular, it resumes all findings in four categories: good communication, equity, foresight, and respect.

***Good communication*** is fundamental to empowering people, avoiding misunderstandings between stakeholders, and increasing trust. Thus, it is helpful to foster community awareness and, consequently, the support of initiatives by the broader public. To make good communication, evaluations of previous initiatives highlight the importance to (i) adopting a common, simple, and straightforward language, avoiding being too technical and scientific, (ii) ensuring clearness and transparency to foster trust, and (iii) promoting communicative initiatives as festivals and meetings which are opportunities to create spaces for dialogue between different stakeholders and to diffuse results and good practices achieved through environmental interventions. ***Equity*** is a fundamental prerequisite to achieving effectiveness in collaborative activities, leading to trust and respect across all people involved. To achieve equity is fundamental to ensure (i) impartiality, (ii) the involvement of local stakeholders who really know the needs and challenges to be faced where they live, (iii) mediation by external actors to avoid conflicts of interest, (iv) the respect of privacy, (v) equal time-allocation in participative processes to limit the influence of elites, and (vi) the support of bottom-up initiatives which represent relevant interventions needed by the local population. Additionally, from the review emerges that environmental transformations require long-term processes despite the short-time nature of most environmental projects. This is why interventions need to be designed and developed using ***foresight***. Foresight implies (i) institutional stability, meaning the permanent involvement of central actors in multiple interventions, (ii) solid and coherent planning instruments which support relevant interventions, (iii) continuity in actors' engagement through periodic meetings to avoid stakeholder apathy, (iv) incentives to support private investments through public-private partnerships, (v) transdisciplinary approaches able to cope both social and ecological challenges, and (vi) spaces for innovation developed by fruitful collaborations between scientific and private bodies. Finally, ***respect*** for the ecological, social, and cultural contexts where interventions act requires (i) dynamic and flexible regulations and policies which allow adaptability and integrations, (ii) cultural and ecological contextualization of activities which must consider traditions of population and ecological characteristics of the area, and (iii) participative evaluations which allow identifying real needs and challenges taking in consideration the local perspective of stakeholders.

Consequently, considering the literature review's results, the following two papers ***aim to develop a network approach to evaluate environmental projects' effectiveness***. Through the analysis of the LIFE-NAT project in Italy (paper 2) and Veneto region (paper 3), studies analyze ***partnerships*** and ***intervention areas*** of such collaborative environmental activities to verify if they follow criteria identified by the literature review and to propose improvements to increase the effectiveness of the LIFE Programme. Specifically, due to the nature of the secondary data used for the analysis, it is not possible to investigate all requirements identified by the literature review. Thus, the paper focuses primarily on: (i) involvement of local stakeholders, (ii) mediation by external actors, (iii) bottom-up initiatives, (iv) solid and coherent planning instruments, (v) continuity in actor engagement, (vi) transdisciplinary approaches, and (vii) cultural and ecological contextualization.

**Paper 2** focuses mainly on social relations emerging through LIFE project partnerships of actors sharing resources to achieve a common environmental objective. In particular, through the explorative analysis of LIFE-NAT projects implemented in Italy in the last programming period (2014-2020), the study uses descriptive network statistics to verify the ***existence of horizontal and vertical collaborations*** concretized through heterogeneous partnerships, integrating the theoretical concepts of ***multi-actor and multi-level governance*** to the adaptive governance framework. Furthermore, by proposing a valuation approach based on SNA to analyze LIFE-NAT project partnerships, the study could help identify the most suitable combination of beneficiaries constituting project partnerships for the LIFE Programme purposes. In this way, it could set a background for enhancing future design, implementations, and evaluations of environmental activities placed locally but sustained at the EU level through projects to concretize the "*Think global, act local*" vision of sustainable development.

Results of the analysis attest to the existence of heterogeneous LIFE-NAT project partnerships, which allow the concretization of multi-level and multi-actor governance in the collaborative governance of biodiversity sustained by the LIFE Programme. ***Public actors represent most partners, and protected areas managers are the most central actors in the network, allowing transversal collaborations with all types of actors***. Conversely, results highlight the need to incentivize a higher involvement of private actors who live where interventions act and directly benefit from project outcomes. Their reduced participation is probably due to the high skill and financial resources required to manage EU funds like LIFE projects directly. Therefore, investments for capacity building and different modulation of their financial contribution are needed to

support their participation. Additionally, this study represents the first attempt to analyze social-ecological interdependencies affecting environmental challenges, revealing that conservative interventions selected by the study are strictly connected with social and economic peculiarities of organizations and institutions which foster interventions and areas where they are implemented. In effect, LIFE-NAT projects are implemented especially in areas where wildlife is recognized and valorized not only for its intrinsic value but also for its role in economic activities and the availability of ecosystem services. Consequently, it shows that ***effective collaborations in collaborative environmental governance could be analyzed only if evaluations concern both social and ecological components of interventions***.

**Paper 3** enlarges the field of analysis by proposing a novel approach able to evaluate the collaborative environmental governance adopting a social-ecological perspective, focusing on both LIFE project partnerships composition and ecological elements involved in LIFE-NAT projects, *i.e.,* ecological connectivity of Natura 2000 sites through ecological corridors, and synergies across freshwater, land, and marine habitats through the analysis of protected habitats. In this way, it can analyze social-to-social, social-ecological, and ecological-to-ecological interactions, enriching the theoretical concepts and frameworks used in Article 1 and Paper 2 through the SEN approach. Even if the study concerns LIFE-NAT projects implemented in the Veneto region (Italy), ***the proposed approach is entirely replicable in all EU territories*** because are used standardized information collected in the LIFE Programme database for all LIFE projects since 1992. Additionally, it is characterized by statistical robustness because of the use of ERGMs, which allow the detection of tendencies in collaborative environmental governance that conventional evaluation methodologies cannot trace.

Thus, the ***study contributes to finding criticisms and challenges to improve the collaborative environmental governance of protected areas*** (*e.g.,* the social-ecological fit of governance initiatives and the active engagement of local stakeholders). Consequently, it is possible to obtain recommendations that give indications to policymakers and practitioners about intervention areas, conservation objectives, and partnerships composition able to concretize transversal and coherent governance for nature and biodiversity. In particular, the study focuses on the concretization of multi-actor and multi-level governance and the capacity of LIFE-NAT projects to stimulate ecological connectivity and synergies across freshwater, land, and marine habitats. Results demonstrate that selected ***LIFE-NAT projects promote polycentric governance but fail to foster multi-level and multi-actor governance***. Specifically, following the results of

paper 2, the analysis highlights a low involvement of private bodies (enterprises and not-for-profit bodies), especially at a local jurisdictional level. Focusing on the implementation area of LIFE-NAT projects, the analysis reveals that multiple LIFE-NAT projects act in the same Natura 2000 site proving that LIFE-NAT projects are helpful for the achievement of conservation objectives but are limited by time and resource allocation that are circumstantiated by specific goals. Additionally, it is verified the ***tendency of selected LIFE-NAT projects to consider the ecological connectivity of sites*** and to support synergic social collaborations among activities spanning across marine, land, and freshwater ecosystems through the transversal role of forests.

**5.2 Research limitations and future research development**

Studies composing this dissertation are subjected to limitations that need to be clarified. Article 1 selected only articles from the SCOPUS database that uses the selected keywords and are written in the English language. This limitation could exclude from the analysis valuable experiences from which it is possible extracting new perspectives and recommendations. Papers 2 and 3 are characterized by constraints related to the absence of a standardized classification of partners involved in the LIFE project. Thus, actor classification could be subject to subjectivity, failing to identify partners correctly. Additionally, Paper 3 results are limited by the lack of statistical software and, consequently, the impossibility of verifying specific network structures affecting the collaborative environmental governance. Additionally, the approach proposed by Paper 3 can be applied only to LIFE-NAT projects because they are the only typology of LIFE projects with standardized information related to the intervention area (*i.e.,* N2000 sites).

The proposed approach could be used to deepen other components of effective collaborations that are identified in the first paper. Therefore, future research on LIFE projects could be enriched by primary data collected, *e.g*., interviews. Furthermore, future research developments could analyze social-ecological relationships at different jurisdictional levels (*e.g*., national or international) or compare evaluations related to other geographical areas characterized by differences in cultures and ecosystems. Additionally, future studies could analyze social-ecological interconnections fostered by LIFE projects from a temporal perspective, focusing on LIFE projects since 1992. Further analyses could explore social-ecological interactions considering LIFE projects that are not included in the LIFE-NAT priority area or could include other attributes to LIFE projects classification (*e.g.*, themes, keywords) to identify synergies across LIFE

projects. Finally, the proposed network approach could be a road map for further studies even beyond the LIFE Programme that could be replicated also outside of EU territory where institutions are structured through multi-level governance (e.g., Latin America).

### 5.3 Policy recommendations

In concluding remarks of every study composing this dissertation are specified practical recommendations derived from the analysis results. This paragraph summarizes them to give a general overview of improvements required to reach effectiveness in collaborative environmental governance initiatives.

Specifically, collaborative environmental governance initiatives concretized through LIFE projects, need to improve the following aspects.

● Foster ***public participation in LIFE project partnerships*** by identifying relevant stakeholders who need to be actively involved in projects, especially local private bodies (i.e., NGOs and enterprises) directly benefiting from LIFE project results. From the literature review, reported in ***article 1***, emerges the need to foster public participation using participative approaches in all phases of the project cycle to obtain a real impact of projects. If stakeholders are actively involved in activities, they will play a fundamental role through their knowledge about where the activities are placed. In particular, they are determinant in identifying relevant social and ecological problems affecting the specific area where interventions are placed and, consequently, the identification of shared solutions able to address multiple needs of diverse stakeholders. Consequently, when involved, local actors can increase the effectiveness of environmental interventions by determining a real impact. ***Papers 2 and 3*** demonstrate the ability of the LIFE programme to stimulate polycentric governance through the co-financing of LIFE projects which are tools able to concretize bottom-up initiatives proposed by partnerships of actors. Nevertheless, if ***paper 2*** detects the presence of heterogenous partnerships in Italian LIFE-NAT projects, ***paper 3*** demonstrates the failure of LIFE-NAT projects placed in Veneto Region in concretizing multi-actor governance. In particular, ***both papers*** highlight the prominent role of public bodies in LIFE-NAT partnership composition and the marginal presence of local private bodies such as enterprises, which directly benefit from ecosystem services improvements, and NGOs. Their reduced involvement could limit the effectiveness of LIFE-NAT projects, reducing the environmental awareness of the community and, thus, its support of interventions.

● Support the role of ***central actors in environmental management*** (e.g., protected areas managers, universities, research centers, regional authorities), promoting continuity in their presence in multiple LIFE project partnerships. This is motivated by the need for long-term initiatives to foster sustainability transformations, as highlighted by ***article 1***. Despite the short-term nature of projects, the literature review highlights the fundamental importance of institutional stability, which is helpful in reducing stakeholder apathy and ensuring the continuity of activities. In particular, ***paper 3*** reveals that a single Natura 2000 site could be involved in more than one LIFE-NAT project, attesting that LIFE projects represent opportunities to foster ecological interventions. However, they could not exhaustively face the entire conservation challenges of a specific Natura 2000 site because they are limited in time and resources. Consequently, they require continuity of interventions in the long-term, which the LIFE Programme could sustain. To be effective such interventions need to be characterized by institutional stability through the maintenance of central actors in all interventions to avoid redundancies and waste of resources. Through network analysis of LIFE-NAT project partnerships reported in ***papers 2 and 3***, we identify public actors, specially protected areas authorities, universities, and research centers as the most central actors able to make transversal relationships with all types of stakeholders. Therefore, they can catalyze long-term collaborations through the proposal of multiple LIFE projects through the involvement of multiple and different stakeholders, from which derives the identification of multiple solutions and best practices.

● Propose ***interventions aimed to improve both ecological and social conditions of areas*** where they are implemented. Results from ***article 1*** highlight that most of the interventions analyzed by the literature review are related to the sustainable use of resources and consider environmental projects as opportunities to improve the social well-being of populations. Therefore, effective environmental initiatives must consider ecological issues and the social and cultural context where interventions occur. In this way, it is possible to effectively identify real problems affecting the community. This tendency is also demonstrated by ***papers 2 and 3***, attesting that LIFE-NAT projects have not only the objective of conserving biodiversity merely but also catalyzing activities to create opportunities to increase social well-being. Specifically, in northern Italy, interventions aim to restore degraded areas and thus increase the quality of ecosystem services in a high-population and polluted area like the Po Valley. On the other hand, in the center-south of Italy, LIFE-NAT projects are mostly localized in inner areas characterized by the reduced availability of services and depopulation. They are conceived as opportunities to sustain the sustainable development of such areas.

● Better ***communicate with simple and clear language environmental challenges*** faced by interventions and solutions they propose, involving the local community to stimulate environmental awareness. Therefore, community environmental awareness is seen as the critical factor in making environmental interventions effective. This is highlighted by the results of ***article 1***, which specify the need to improve environmental communication using clear and simple language and innovative tools like visual methods. This is important to avoid misunderstandings between stakeholders and increase trust in institutions. The fundamental role in the communication and dissemination of information is mainly covered by universities, research centers, and not-for-profit bodies, which effectively are central categories in LIFE-NAT partnerships analyzed in ***papers 2 and 3.*** Thus, stimulating environmental awareness is one of the main objectives of the LIFE Programme, which could be reached if the results of LIFE projects are diffused and communicated to the community. Nevertheless, ***paper 3*** detects the need to mainly include not-for-profit bodies in LIFE-NAT project partnerships to clarify better and enhance the active participation of local stakeholders at local and sub-national levels. Stimulating environmental awareness at the local level is fundamental for the formulation of new LIFE-NAT projects and the involvement of local stakeholders in them, as shown by ***paper 3*** where multiple LIFE-NAT projects are placed in the Venice Lagoon, which people perceive as an area with a significant cultural and natural value frightened by multiple environmental challenges due to pollution and climate change.

● Promote ***educational activities for the local community and local public authorities*** or protected areas managers to empower them. Environmental activities are considered in ***article 1*** as educative tools to empower the community and foster environmental awareness. Education and empowerment of local bodies are required to achieve the effectiveness of collaborative environmental governance. ***Papers 2 and 3*** highlight the need to increase investments for capacity building of local bodies to give them adequate skills to directly manage EU funds through, e.g., their coordinating role in LIFE projects. Supporting local bodies in their proactive involvement in LIFE-NAT project partnerships could stimulate additional collaborations between actors because they are intrinsically prone to relate with other territory stakeholders, revealing their fundamental brokerage role due to their institutional characteristics.

● ***Collaborate with other LIFE projects and promote the exchange of good practices and resources*** with other managers of protected areas to foster connectivity, coherence, and integration in the governance of

nature and biodiversity. Accordingly, from the literature review in ***paper 1*** emerges the need to sustain multi-level and multi-actor collaborations ensuring spaces for dialogue across stakeholders to guarantee the maintenance of good practices in the management of biodiversity and to avoid misunderstandings and redundancies. ***Paper 2***, through the analysis of LIFE-NAT projects partnerships, identifies national and transnational collaborations between protected areas managers. Nevertheless, it highlights the need to improve coordination between actors working at different jurisdictional levels, especially the involvement of local bodies, which often have the institutional role of managing Natura 2000 sites, whose involvement, at present, is low. This way, it is possible to concretize the "*think global and act local*" perspective that characterizes sustainable development. Additionally, the analysis reported in ***paper 3***, which also considers ecological characteristics of Natura 2000 sites involved in LIFE-NAT projects, highlights that collaborations between projects tend to be created when projects share similar habitats, highlighting the need for incentive integrations of governance practices between different contexts ensuring coordination and coherence across multiple and different Natura 2000 sites.

● Stimulate ***ecological connections and synergies across freshwater, land, and marine habitats proposing activities in multiple and different sites*** or selecting transition areas (e.g., estuaries) characterized by the richness in habitat and species diversity. From the results of ***article 1*** emerges the necessity to always adopt a broader perspective because a SES is not limited to narrow boundaries but is susceptible to external changes. This is why fostering synergies and integrations across different habitats is essential. The analysis reported in ***paper 3*** highlights that LIFE-NAT projects in the Veneto region consider a wide range of land, marine, and freshwater habitats, sustaining the ecological connectivity of the Natura 2000 network. It is also attested that LIFE projects are frequently placed in transition habitats, like the lagoon or rivers, where multiple biological, geochemical, and social processes are strictly intertwined. Nevertheless, despite the identification of the bridging role of forest habitats, the analysis detects that collaborative relationships emerge mostly when projects share similar habitats, especially if they are marine, highlighting the need to adopt a more strategic vision in the governance of biodiversity which considers that species live and move across different habitats which are all fundamental for their existence.

Operatively, improvements identified by this research require new approaches and strategies that need to be adopted by the LIFE Programme authorities (EU Commission) and practitioners who propose and implement interventions.

To foster environmental awareness and sustainability transformations, LIFE projects must directly involve local people in LIFE project activities. For example, **public surveys during the identification of LIFE project objectives** help create legitimation and trust between LIFE beneficiaries and the community. Similarly, **citizen science activities monitoring LIFE project progress could provoke multiple benefits** enhancing public awareness and support and providing additional resources for LIFE project activities. This initial involvement should be kept along the entire life of the project. Local actors should be continuously informed about project advancements and achievements, to keep an active interest on the environmental problem tacked by the projects. Therefore, community participation must also be valorized by the LIFE Programme authorities, which could sustain it through the **elaboration of output and outcome indicators focused also on local participation and its effects**, enhancing the monitoring of LIFE project activities.

Furthermore, at the end-of-LIFE projects, **participative evaluations** could reveal new aspects that normally are not taken into consideration by evaluators of LIFE projects, *e.g.*, cultural values. Generally, the active involvement of the local community facilitates its commitment and allows the effectiveness of LIFE project initiatives and extends its benefits after its end. The engagement of the local community could complement the actions that normally take place in the so-called post-LIFE of the project, where the initial partnership of the project commits itself to continue to produce the outputs and results although without the external co-financing. Consequently, LIFE projects could enhance their effectiveness in the long-term - where it is already required the specifications of the activities after the end of the projects - by clearly involving the local community in different tasks. In this way, the sustainability of results, which is a clear commitment in the grant agreement, would be facilitated and this would benefit the impacts. This is why is fundamental that post-LIFE indicators focused on the impact of the project concern not only ecological effects, but also social ones.

Additionally, LIFE projects currently lack effective communication, which relies mainly on using the LIFE project website, or newsletters, of social media. Firstly, the requirement established by the LIFE Programme authorities to create a new website for every new LIFE project cause **fragmentation of LIFE project**

**information**, representing a limitation that needs to be addressed as soon as possible. **Creating a central communication platform** at the EU level that is specifically devoted to diffuse communication on project results and impacts – beside the already existing platforms such as the "Project database", the "Nature 2000 viewer" and the "GIS database of the projects" – and directly managed by the LIFE Programme authorities by merging all contents across all LIFE project websites could give coherence and promote effective communication, that would be useful for different stakeholders (e.g., project designers, managers and evaluators, national, regional and local authorities, civil society organizations active in environmental initiatives, local enterprises). Additionally, LIFE projects need to enhance their communication capacity by using i**nfographics** and **slogans** which resume projects objectives and benefits. Additionally, it is fundamental that **communication has to address a more comprehensive public, not only experts.**

Thus, educational activities must be **formal** through, *e.g.*, European programming or environmental education courses, and **informal** through, *e.g.,* graphical contents on social media and films or book clubs. Therefore, LIFE projects need to involve or create **informal groups composed by voluntary people,** characterized by environmental or territorial interests, to spread project information and foster community awareness. In this way, LIFE projects could enhance their interventions by acquiring new knowledge and resources and simultaneously spreading information. **Proposing experiences** (*e.g.,* field trips, camping in natural contexts) for local communities is helpful to increase environmental awareness and foster education. Communication cannot be limited to spreading ecological information, but it can also rely on **arts, culture, and spirituality** to better stimulate community perceptions about the value of nature. Accordingly, it is fundamental to highlight the ecological or economic benefits of LIFE project activities and their **positive impact on social, cultural, and psychological well-being**. So, during the identification of LIFE project objectives, is fundamental to identify the social and psychological benefits of LIFE interventions, which are complementary to ecological and economic benefits usually detected and reported in the LIFE project description. Consequently, whoever proposes LIFE projects must identify the source of the environmental problem that activities aim to address and, when possible, **involve economic activities** that foster such environmental issues in the LIFE project partnership.

Studies reported in this dissertation highlight that the structure of partnerships is fundamental to achieving effectiveness. So, it is essential to identify the best composition of partners to be included in the proposal of

a new LIFE project. **Involving central actors who already have experience** in addressing specific environmental challenges or acting in a particular territorial context is fundamental. Despite recognizing the critical value of the "*learning-by-doing*" process, at present does not exist a public, user-friendly source of information related to past and current LIFE projects. Even if such information is reported in the LIFE Programme database, it is hard to understand and identify relations across projects, environmental challenges, and implementation areas. So, it could be helpful that LIFE Programme authorities **will design and make public a new user-friendly tool** similar to the Natura 2000 network viewer (https://natura2000.eea.europa.eu/) where all LIFE projects and LIFE beneficiaries are reported and georeferenced and characterized through the identification of environmental challenges addressed or protected habitats or species they aim to conserve. Additionally, **enriching this tool using SNA** descriptive statistics could be helpful to identify **central actors** in a specific territory or in a specific environmental challenge to be faced, but also clarify ecological connections that need to be preserved or restored (*e.g*., ecological corridors, transition habitats). LIFE project partnerships could also use the proposed tool to **identify other LIFE projects sharing similar objectives** to enhance the exchange of new solutions and practices derived from multiple experiences.

Collaboration across LIFE projects is already stimulated and supported by the LIFE Programme, which requires identifying LIFE projects with similar purposes. Nevertheless, an effective transversal exchange of experiences and practices could be sustained by **in-person and compulsory events** organized by the LIFE Programme authorities where LIFE beneficiaries have to show what they are doing. In this way, it is possible that new collaborations across projects can emerge, especially between projects operating in different geographical areas. Additionally, creating a **shared platform open to all LIFE beneficiaries** with reported activities, educational material, the result of public participation, *etc*., could help identify new collaborations or practices adopted by other interventions. Furthermore, the LIFE Programme authorities could foster such a process of collaboration across LIFE projects requiring the identification of other LIFE projects which can replicate results at the end of every LIFE project.

# Part 2: Complementary articles

This second part presents two articles complementary to the studies composing the first part of the dissertation. In both of them, I was involved in data analysis and interpretation, as highlighted in table 1.1. Specifically, **Article A** represents the starting point of LIFE project analyses, so it clarifies challenges to be dealt with in the study and the first preliminary results. **Article B** reports a general and explorative analysis of LIFE-NAT project partnerships highlighting general tendencies in the governance of EU countries, setting a baseline for Papers 2 and 3, which specifically focus on LIFE-NAT project implementations in the Italian context.

## Article A

***Intermediary organisations in collaborative environmental governance: evidence of the EU-funded LIFE sub-programme for the environment (LIFE-ENV)***

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**Abstract**

In the framework of the collaborative environmental governance and specifically of network concepts, this study makes an exploratory analysis of the EU-funded LIFE sub-programme for the Environment (LIFE-ENV) and its priority area Environment and Resource Efficiency focused on the role of networks and in particular of intermediary organizations by using Social Network Analysis (SNA). More specifically, by investigating the evolving pattern of key statistics (density, clustering coefficient, betweenness and degree centrality) related to bipartite (organisations and projects) and dynamic (eleven years) networks, we identified 3003 organisations and 1006 projects and studied how they operate by forming new relations and reorganising existing connections. Results evidence that the LIFE-ENV attests a structural coherence and a stable structure over time and it is characterised by four different structures of network components, namely isolated

coordinating beneficiary, isolated components, small components and giant components. Moreover, the LIFE-ENV is not a cohesive network, due to low values of both density and clustering coefficient. Based on betweenness centrality and degree centrality measures, the LIFE-ENV sub-programme has facilitated the emergence of 4855 intermediary organisations, which equals 29.5% of the total number of coordinating and associate beneficiaries involved in the programme in the eleven years considered. Transnational cooperation in the LIFE-ENV sub-programme is characterised by a different intensity of relations: some countries (*i.e.* Italy, Spain and Belgium) implement transnational cooperation with multiple European countries in both the North and South of Europe, while others tend to cluster with countries in the same geographical area, and lastly East European countries have limited participation in transnational cooperation. Our analysis supports the hypothesis of a declining collective action in the LIFE-ENV sub-programme.

*Keywords: Economics; Environmental science; Political science; Collaborative environmental governance; Network environmental governance; Intermediary organisations; Degree centrality; Betweenness centrality; Density; Clustering coefficient; EU financing; Two-mode networks; Bipartite networks.*

**Introduction**

Economic activities may lead to the intensive and often irreversible consumption of natural capital. Based on time series from 1990 to 2014, Ahmad *et al.* (2018) estimate that in the next 30 years the natural capital in 140 countries will continue to decrease in quality and quantity. Moreover, by projecting the current trends in the future, the authors find that countries with low human and produced capitals, but high natural capital (*e.g.*, Brazil, Republic of the Congo and the Islamic Republic of Iran), will fail to sustain their natural capital in the near future. Humanity is entering in the Anthropocene, a new geological era where human agency is at the centre of the temporal and long-term problems of the earth system (Crutzen and Stoermer, 2000; Crutzen, 2002; Steffen *et al*., 2011; Dash, 2019). With agricultural and industrial revolutions humans came to dominate the earth's biophysical processes. At the same time, they caused a significant state shift in the earth's biosphere threatening to disrupt human civilisation (Gowdy and Krall, 2013).

In response to these worldwide environmental and human challenges, the scientific literature highlights the effectiveness of multiple governance approaches to manage temporal and long-term environmental problems that cross different geographical and temporal scales and include diverse jurisdictions and

organizational hierarchies (Bodin *et al.,* 2016). Studies on the positive effects determined by environmental governance are proposed by Todić and Zlatić (2018), Lipponen and Chilton (2018), and Dinar *et al*. (2019) concerning water and groundwater management, by Zinesis (2017) and Fernandes *et al*. (2019) for nature conservation, and by Ilankoon *et al.* (2018) for waste management. By engaging public and private actors and stakeholders, collaborative environmental governance (hereinafter CEG) aligns human actions to ecosystem protection by proposing effective solutions through learning processes, coordination and cooperation (Bodin, 2017). This approach is also relevant to policy makers. By conveying that environmental challenges cannot be resolved merely at a national level, the European Union (EU) sustains multi-level governance based on cross-border cooperation among social and institutional actors with diverse backgrounds, interests and objectives to tackle environmental challenges at different levels, scales and dimensions (European Commission, 2014). Among the various European funds, the EU Programme for the Environment and Climate Action, better known with the acronym LIFE, aims to finance projects based on a collaborative governance approach to reach the EU environmental objectives. Specifically, the LIFE sub-programme for the Environment supports the efficient and respectful use of natural resources and the implementation of environmental policies through different thematic priorities (namely: water management, waste management, promotion of the circular economy, sustainable use of soil and forests, containment of the use of chemicals, noise, air and the urban environment). Since its creation in 1992, LIFE has co-financed more than four thousand projects in 28 European countries, thus becoming the largest and most relevant funding programme for environment sustainable management in Europe. The LIFE programme ultimately aims to catalyse synergies among actors, to promote and disseminate good practices and best solutions needed to achieve environmental and climate change objectives and to encourage innovative and eco-friendly technologies (EU Regulation No. 1293/2013), by promoting networking and knowledge sharing.

The scientific literature shows that synergies between multiple institutional and social realities facilitate sharing of different skills, knowledge and resources. These are useful to reach a new equilibrium in the balance between human agency and natural resources (Li and Mauerhofer, 2016; Sayles and Baggio, 2017; Baggio and Hills, 2018; Barnes *et al.,* 2019). Nevertheless, as Bodin (2017) observes, CEG also testifies to criticisms in multiple circumstances (*e.g.,* the time required to overcome initial collaborative barriers, such as lack of trust; environmental hazards calling for immediate top-down actions; environmental issues particularly contested by the civil society and characterised by high asymmetry in power relations of

stakeholders). In addition, information sharing among actors does not necessarily determine per se changes in values, beliefs, and behaviours and, consequently, desired outcomes (Mont *et al*., 2014). Thus, studies evidencing when and how CEG is effective are much needed, by focusing on who are the actors involved, with whom they collaborate, how these collaborative networks are formed and how they address different environmental problems by considering –among others– the temporal and spatial features of the ecosystems (Crona and Bodin, 2006).

In more detail, within the broad realm of collaborative environmental governance we can refer to the concept of network governance (Rhodes, 1996, 1998) (hereinafter NG), which is becoming an increasingly popular approach for dealing with complex and dynamic issues that characterise environmental policies (*e.g.* Aggestam, 2018; Perkins and Nachmany, 2019). Studies have observed the importance of networking in CEG in relation to conservation of nature (Snijders *et al*., 2017), transition to a green economy (Imbert *et al*., 2018), management of protected areas within the Natura 2000 network (Manolache *et al.,* 2018), management of water resources (Lienert *et al.,* 2013; Edens and Graveland, 2014), management of forest resources (Kleinschmit *et al.,* 2018), and analysis of regional governance (Grönholm, 2018). Recent literature has focused on specific research questions such as: (i) why organisations decide to join a governance network (Barrutia and Echebarria, 2019); (ii) how the structural characteristics of the social-ecological network – determined by the specific position of actors in the web of connections– affect the ability of the entire network to solve collective action problems (Bodin, 2017); (iii) how organizations perceive the risk of others defecting from a network and how they reduce the risk by connecting to organisations where trust is already well established (Schoon *et al.,* 2017); (iv) how "intermediaries" or brokers affect the network governance and its dynamics (Beveridge, 2019).

For the purpose of this paper, we would like to focus on this last question which represents a key issue to be observed when analysing huge environmental programmes where multiple actors, who are operative in diverse geographical scales and jurisdictions, operate through transnational cooperation in order to handle common environmental problems through a NG approach. This is exactly the case for the LIFE sub-programme for the Environment within the EU. As mentioned, the purpose of the LIFE-ENV projects is primarily to develop, test and demonstrate political or management approaches, good practices and solutions related to the environmental-related thematic priorities by co-financing different types of

interventions (*e.g.,* pilot and demonstration projects, good practices, integrated projects) with an added value at the European level. The LIFE-ENV network is formed by actors involved in project partnerships composed of coordinating and associated beneficiaries. The coordinating beneficiary is responsible for ensuring implementation of the action, constitutes the single point of contact for the contracting authority, and guarantees the distribution of financial resources as specified in the partnership agreements established with the associated beneficiaries (if any). The coordinating beneficiary must be directly involved in the technical implementation of the LIFE-ENV project and dissemination of its results. The coordinating beneficiary must bear part of the project costs and thus contributes financially to the project budget. The associated beneficiary has to contribute technically and financially to the proposal, being responsible for the implementation of one or several project actions (European Commission, 2018).

In this EU funded programme for the environment, networks and NG clearly have a paramount role in defining effective interventions for natural capital and environmental protection. By observing the structures and dynamics of a network composition it is possible to analyse the presence of central actors or intermediary organisations. Intermediary organisations manoeuvre among other actors in a network, making new relations and reorganising existing connections between individuals or organisations through bridging ties. By occupying a specific central location in a social network, actors can exert influences over others, they have access to valuable information, which can put them at an advantage as brokers (Bodin and Crona, 2009; Abrahams *et al.*, 2019). Studies on intermediaries investigate their roles, interests and motivations, importance and influence, and their impact on networks (Beveridge, 2019; Burt, 2009). In NG, the positive effect of bridging ties extends beyond the exchange of information, knowledge and resources among actors. Over time, these ties can foster normative social values such as trust, sustaining future actions, adaptation capacity, *etc*., or, on the contrary, they can bond actors preventing the others' participation in future initiatives.

In the framework of the CEG and NG concepts, this study makes an exploratory analysis of the LIFE-ENV sub-programme and its priority area Environment and Resource Efficiency focused on the role of networks and in particular of intermediary organizations by using Social Network Analysis (SNA). More specifically, by investigating the evolving pattern of key statistics (density, clustering coefficient, betweenness and degree centrality) related to bipartite (organisations and projects) and dynamic (eleven years) networks, we identify

intermediary organisations and how they operate by forming new relations and reorganising existing connections within the context of the EU LIFE programme.

The study has been detailed in the following guiding research questions:

*Q1. To what extent have organisations and projects within the LIFE-ENV sub-programme been connected?*

*Q2. To what extent have new relations been established among organizations and projects within the LIFE-ENV sub-programme or existing relations ceased? To what extent has the LIFE-ENV sub-programme been cohesive and clustered?*

*Q3. To what extent has the LIFE-ENV sub-programme facilitated the emergence of intermediary organisations? What are the types of organisations that maximise the transmission and control of information and resources among projects? What is the level of influence of these key central actors (degree centrality)?*

*Q4. To what extent has the LIFE-ENV sub-programme financed partnerships across Europe? Which are the countries attesting to a better performance in terms of transnational cooperation for the environment?*

The paper is organised in four sections. After this introduction, section two presents materials and methods, which are detailed for each specific research question. Section three provides the results, again detailed for the four research questions and consequently split into four different sub-sections. Finally, section four presents discussions and conclusions.

**Materials and methods**

SNA allows the NG of the LIFE-ENV sub-programme to be measured and represented graphically by (i) measuring the evolution of environmental collaborations in different moments of time and (ii) observing the dynamic pattern of organisations who enter or exit LIFE-ENV projects by forming or ceasing partnerships. By using the network property of indirect structural relations, SNA reveals the hidden ties among actors who are effectively involved in common activities (Borgatti *et al*., 2014). The study proposes the analysis of the entire set of LIFE-ENV projects referred to the priority area Environment and Resource Efficiency, composed by 1006 initiatives financed from 2007 to 2017 and graphically represented as bipartite networks that consist of two disjointed sets of nodes where ties connect nodes of both sets. Nodes of set 1 are organisations

benefitting from the LIFE-ENV financing, while nodes of set two are projects, and ties among the two sets symbolise the participation of organisations in LIFE-ENV projects as coordinating and associate beneficiaries. In the eleven years considered, the EU has revised the structure of the LIFE programme, which was organised in three components from 2007 to 2013, and two sub-programmes from 2014 to 2020. The data elaborated in this study refer explicitly to projects characterised by the strand "environment" and financed via the LIFE programme in 2007–2013 and 2014–2020. Data referred to 2018 and 2019 are not included in the analysis because not available on the database.

In order to access detailed data and information regarding LIFE-ENV projects, the LIFE website has been consulted (https://ec.europa.eu/environment/life/project/Projects/index.cfm) where the complete database of projects is available since the first edition of the Programme. Querying by theme and period, it is possible to obtain the full list of projects carrying the desired characteristics and thus accessing the general project information (*i.e.,* title, project reference, duration, total budget, EU contribution, project location), and specific information related to the beneficiaries (*i.e.,* coordinating beneficiary, type of organisation, description, and partners except for co-financiers). Data collected from the LIFE projects database were exported into two separate MS Excel spreadsheets. The first one –nodes file– contains all the information concerning the two sets of nodes: beneficiaries, both coordinating and associated (*i.e.,* name, ID number, country), and projects (*i.e.* title, project reference, duration and location). The second file –edges file– includes all the relations established by the different project partnerships (source, *i.e.,* the observed project; target, *i.e.,* the specific coordinating or associate beneficiary; type of relation, undirected). The type of relationship is undirected because the lack of directionality among nodes has been assumed. Data in the spreadsheets have been used as input data for the SNA, implemented via GEPHY® and UCINET® softwares for computation of statistics on two-mode betweenness centrality. Additional statistical elaborations have been performed using R statistical software. The dataset is available at https://data.mendeley.com/datasets/p9yxnh3yyd/2 [DOI: 10.17632/p9yxnh3yyd.2]. From a methodological viewpoint, the analysis has been differently structured by considering each specific research question.

*Q1. To what extent have organisations and projects within the LIFE-ENV sub-programme been connected?*

Organisations involved in the LIFE-ENV programme and its projects represent the nodes of the network. Moving from Schoon *et al*. (2017), we investigate eleven bipartite networks by comparing evolving numbers

of nodes, relations, and components along years. In network analysis, components are sub-parts of the network characterised by ties that interlink through common nodes, creating chains or paths of nodes and linking endpoints indirectly. “Part of the power of the network concept is that it provides a mechanism – indirect connections – by which disparate parts of a system may affect each other” (Borgatti *et al.,* 2013: 2). The aim is to understand how LIFE-ENV sub-programme-related organisations and projects connect over time by considering the evolving pattern of the structural features of different network components. By observing graphical representations and using the statistic called “component” computed by GEPHY, we can determine the number of components and which are the organisations taking part in them. By extracting the data into an excel file, we can isolate different structures characterising the LIFE-ENV networks, allowing the process of aggregation of projects and organisations in the network over time to be evidenced.

*Q2. To what extent new relations among organizations and projects within the LIFE-ENV sub-programme have been established or existing relations ceased? To what extent has the LIFE-ENV sub-programme been cohesive and clustered?*

For a specific year of analysis, the dynamic pattern of relations in the network is formed by two possible situations, *i.e*. (i) “existing relation” and (ii) “ceasing relation” in the network. Moreover, the existing relation is characterised by either an “entering condition” or a “permanence condition”. In other words, the entering condition concerns organisations and projects coming into the network after the selection process and establishing their relations (thus, organisations formalise collaborative relations with others through the selected project). The permanence condition refers to organisations and projects selected in previous years and which are still active in the network due to the implementation of defined activities (thus, they keep their relations for that specific year of analysis). The ceasing relation concerns organisations and projects leaving the network due to the fulfilment of their action. Thus, their formal relations cease, nevertheless their informal relations can of course either continue or cease.

For a longitudinal assessment, the dynamic pattern of networks can be analysed by observing if nodes of the set organisations change their “attribute” of coordinating and associate beneficiaries when moving from one project to another along the timeframe considered. This allows all possible choices to be specified and, consequently, trajectories performed by organisations in the decade. The hypothetical trajectories of coordinating and associate beneficiaries (C and A respectively) are defined in number and can be

longitudinally traced and measured by paralleling two consecutive years where different paths can emerge: a coordinating beneficiary can enter the network (0→C), confirm its role (C→C), or leave the network (C→0). Similarly, an associate beneficiary can join the network (0→A), set its role (A→A), or abandon the network (A→0). Moreover, an associate beneficiary can upgrade its role (A→C), and a coordinating beneficiary can downgrade its role (C→A). The last two cases indicate the condition of an actor starting a new project after having just completed a previous one.

As for questions Q3, Q4 and Q5, different network statistics have to be computed. Specifically, density, clustering coefficient, betweenness centrality and degree centrality.

The density represents the level of cohesiveness of the network. The graph density represents the proportion of observed connections between nodes to the maximum number of possible connections. It also reflects the degree of interconnectivity between nodes. In the case of a bipartite network, the density is computed as "the number of edges divided the number of pairs of nodes using unordered pairs in the case of undirected graphs" (Borgatti and Everett, 1997: 254). In the case of bipartite networks only relations between the two sets of nodes are possible. Consequently, the density formula for an undirected bipartite network suggested by the authors is:

$$(1) \qquad D = \frac{n_{org} n_{proj}}{(N_{org} + N_{proj})(N_{org} + N_{proj} - 1)}$$

where $n_{org} n_{proj}$ is the number of relations among the two sets and the denominator computes the maximum possible numbers of relations among the two sets ($N_{org}$ and $N_{proj}$ are the total number of nodes in the two sets).

The clustering coefficient relates to the tendency of nodes to aggregate together by forming densely connected groups within the network. Thus, a high clustering could relate to a higher level of collaborations within the network where organisations collaborate with others based on trust relations or perceived trustworthiness of nodes. However, it could be connected to a higher level of bonding relations among similar actors unwilling to collaborate with other external actors and thus limiting the possibility of future

collaborations with new actors. The clustering coefficient can be computed as a global clustering coefficient measuring the overall level of clustering in the network or a local clustering coefficient observing how a specific node clusters with its neighbours. In the case of a one mode network, the global clustering coefficient is measured as the proportion of closed number of triplets (*i.e.* three nodes connected by three ties) over the total number of triplets in the network (*i.e*. three nodes connected by two ties), while the local clustering coefficient is the fraction of the number of actual ties among node i's contacts over the possible number of ties among them. In the case of bipartite networks, there are different methods to compute the clustering coefficient. In this research, we use what has been proposed by Opsahl (2013), who identifies new indicators for computing clustering coefficients for bipartite networks without using the projection of a bipartite network into a one-mode network, which is normally characterised by an overestimation of the clustering coefficient. Opsahl (2013) formally defines the clustering coefficient as:

$$(2) \quad C^* = \frac{Closed\ 4\ paths}{4\ paths} = \frac{\tau * \Delta}{\tau_*}$$

where τ* is the number of 4-paths in the network, and $\tau * \Delta$ is the number of these 4-paths that are closed by being part of at least one 6-cycle (*i.e*., a loop composed by six ties connecting five nodes), which could range between 0 (minimum value) to 1 (maximum value).

*Q3. To what extent has the LIFE-ENV sub-programme facilitated the emergence of intermediary organisations? What are the types of organisations that maximise the transmission and control of information and resources among projects? What is the level of influence of these key actors?*

Betweenness centrality index can be used to understand whether the LIFE-ENV sub-programme has facilitated the emergence of intermediary organisations. In fact, it measures "the frequency with which a point falls between pairs of other points on the shortest or geodesic paths connecting them" (Freeman, 1978: 221). Thus, the betweenness of a node i is defined as the fraction of shortest paths between pairs of nodes in a network that passes through i. The betweenness centrality evidences a key feature of a node in the network, specifically its capacity to act as a gatekeeper by facilitating the stream of what passes through the web of connections. A node's betweenness centrality equals zero when the node is never along the shortest path between two other nodes (*i.e.,* the node is isolated). When the node lies along every shortest path between every pair of nodes, the betweenness centrality reaches the maximum value. If nodes with higher

betweenness centrality measures were removed, the functioning of the entire network would be compromised due to its reduced bridging capacity among clusters. Betweenness is considered a measure of the influence of the node on the entire network. A central node can be an intermediary organisation playing a key role in the implementation of the LIFE-ENV programme. In the case of bipartite networks, the procedure proposed by Borgatti and Halgin (2011) for the analysis of 2-mode data has been implemented. Formally, the betweenness is computed as in an ordinary graph:

$$(3) \qquad b_k = \frac{1}{2} \sum_{i \neq k}^{n} \sum_{j \neq k,i}^{n} \frac{g_{ikj}}{g_{ij}}$$

where $b_k$ is the betweenness of the node *k*, $g_{ikj}$ is the number of geodesic paths between *i* and *j* that pass through *k,* and $g_{ij}$ is the total number of geodesic paths that pass from node *i* to node *j*. In the case of the bipartite networks, the values of $b_k$ have to be normalised for the maximum betweenness that any node can achieve in a graph of $S_1$ organisations and $S_2$ projects formalized by Borgatti and Halgin (2011).

The degree centrality, $d_i$, represents the number of relations that a specific node has and it is normalised by dividing by the maximum number of possible ties, $d_i^* = d_i/(n-1)$. Thus, in the case of LIFE-ENV network, degree centrality measures the level of influence or the level of involvement that a $j_{org}$ node or an $i_{proj}$ node has on the entire network of collaborations (Opsahl et al 2010). In the case of bipartite networks, ties are only among the two sets. Consequently, the normalised degree centrality can present two different formulas:

$$(4) \qquad d^*_{j_{org}} = \frac{d_{j_{org}}}{N_{proj}} \quad for\ j_{org} \in S_1$$

$$(5) \qquad d^*_{i_{proj}} = \frac{d_{i_{proj}}}{N_{org}} \quad for\ i_{proj} \in S_2$$

In the case of (4), a node belonging to the first set ($S_1$) can be connected to a maximum number of ties equals to $N_{proj}$ while in the case of (5) a node in the second set ($S_2$) can be connected to a maximum number of ties equals to $N_{org}$. The focus on this study is on intermediary organisations which are considered as primary nodes, observing that it is the organisation which decides to take part to the project and not *vice versa*, so formula (4) will be used for computation. This measure focuses on the local structure around the node by

evidencing its level of influence in the surroundings, but it does not consider the entire structure of the network. So, a node could have a high degree but, at the same time, it could be located in a part of the network not well connected to others, undermining its capacity to act as intermediary in the flow of resources and information (Opsahl *et al.* 2010).

The two measures of centrality –*i.e.,* betweenness and degree centrality– represent two different concepts. In a one mode network, a node with a high degree centrality endows a large number of connections, but it could belong to a unique partnership (thus, with zero betweenness centrality). In this case, the high degree centrality is not indicative of a higher capacity to control whatever flows in the network. When considering betweenness centrality, instead, the main focus is on the presence of nodes acting as brokers in the network. The betweenness is usually interpreted as the potential of the node to control the flows through the network acting as a gatekeeper or a toll-taking actor. Moreover, those actors normally filter the information, so many nodes need that specific node to reach others by using an efficient path (*i.e.,* the shortest). Of course, these concepts have to be adapted to the case of 2-mode networks, by considering the previously presented formula.

*Q4. To what extent has the LIFE-ENV sub-programme financed partnerships across Europe? Which are the countries attesting a better performance in terms of transnational cooperation for the environment?*

The transnational cooperation can be represented graphically by using two specific layouts of the GEPHY software, specifically Maps of Country and Geo-Layout. Based on information on the national or transnational composition of the partnership for each specific project it is possible to graphically represent with weighted ties the connections among countries in terms of transnational cooperation.

**Results**

From 2007 to 2017 the priority area Environment and Resource Efficiency in the LIFE-ENV Programme has co-financed 1006 projects, reaching 1006 coordinating beneficiaries and 3363 associated beneficiaries. Thus, a total number of 4369 organisations distributed in the 28 European countries have benefitted from the European financing system for the environment and some of them more than once. In fact, the total number of “single” organisations participating in LIFE-ENV Programme were 3003, of which 1366 (45.5%) decided to repeat their participation in different years and also with different roles. In the eleven years considered by

our analysis, the countries most benefitting from LIFE-ENV financing have been Spain (337 projects) and Italy (262), followed by France (63) and Greece (58). The average financial dimension of a single LIFE-ENV project is 3,106,712 euro (with a minimum value of 417,759 euro, a maximum of 21,424,942 euro, and a standard deviation (SD) of 2,894,458 euro). In the programming period 2007–2013 (the first 7 years of our dataset), the European Commission contributed to financing a total budget of 1,973,187,801 euro to LIFE-ENV projects, while in 2014–2017 (the last four years of our analysis) the amount was 568,834,190 euro.

*R1. Nodes and structures of network components*

From 2007 to 2017, the 1006 projects have on average 4.4 relations each. For each of the eleven years considered, a network has been built and descriptive statistics computed. Descriptive data on networks built are summarised in Table 1, in which only three years (namely 2007, 2012, 2017) are described as examples, focusing on the evolving pattern in the total numbers of coordinating beneficiaries, associate beneficiaries, projects, nodes, relations, components, and budget of the actions.

*Table 1. Descriptive statistics of the LIFE-ENV programme from 2007 to 2017. Source: our elaboration based on LIFE dataset*

| ***LIFE-ENV*** | | ***2007*** | ***2008*** | ***2009*** | ***2010*** | ***2011*** | ***2012*** | ***2013*** | ***2014*** | ***2015*** | ***2016*** | ***2017*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Coordinating beneficiary* | (C) | 72 | 99 | 116 | 103 | 113 | 147 | 128 | 55 | 56 | 62 | 55 |
| *Associate beneficiary* | (A) | 286 | 301 | 402 | 319 | 345 | 424 | 385 | 212 | 228 | 249 | 212 |
| *Organisations* | (C)+(A) | 358 | 400 | 518 | 422 | 458 | 571 | 513 | 267 | 284 | 311 | 267 |
| *Projects* | (P) | 72 | 99 | 116 | 103 | 113 | 147 | 128 | 55 | 56 | 62 | 55 |
| *Nodes* | (C)+(A)+(P) | 430 | 499 | 634 | 525 | 571 | 718 | 641 | 322 | 340 | 373 | 322 |
| *Relations* | Number | 358 | 758 | 1276 | 1698 | 2147 | 2574 | 2725 | 2553 | 2388 | 2220 | 2004 |
| *Components* | Number | 61 | 100 | 128 | 150 | 177 | 195 | 200 | 186 | 178 | 153 | 151 |
| *Total Budget per year (EU28)* | Thousand Euro | 180369 | 334021 | 270102 | 265116 | 292670 | 304150 | 326759 | 121039 | 142177 | 139139 | 163442 |

The number of coordinating beneficiaries (which corresponds to the total number of projects financed) evolves in the timeframe considered: it starts from 72 in 2007, then reaches its maximum value of 147 in

2012 before descending to 55 in 2017. The number of associate beneficiaries follows a similar path: it equals 286 in 2007, touches its highest value (424) in 2012, and then descends to 212 in 2017. The three networks are characterised by a number of nodes totalling 430 in 2007, 718 in 2012 and 322 in 2017. Both organisations (mode 1) and projects (mode 2) are connected through 358 relations in 2007, which rise to 2574 in 2012, and finally descend to 2004 in 2017. Table 1 also reports the budget for all the LIFE-ENV projects financed across the EU during the eleven years considered (see "The LIFE-ENV 2007–2017 dynamic and bi-partite graph" in Supplementary Materials).

Figure 1 presents the three networks for the three selected years (2007, 2012 and 2017). Analysing the graphical representation of these networks, one can observe their structural evolution during the time considered: from a first network of 61 quite homogeneous and very small components (2007), to other two networks with 195 and 151 components (in 2012 and 2017 respectively). The most distinctive feature emerging by comparing the three graphs is the presence of a giant component in both the second and third network, while this feature is not present in 2007. The graphic representation also highlights the substantial increase in the number of nodes and relations from the first network to the second and third ones. Table 2 specifies the key structural features of the different components in the three graphs.

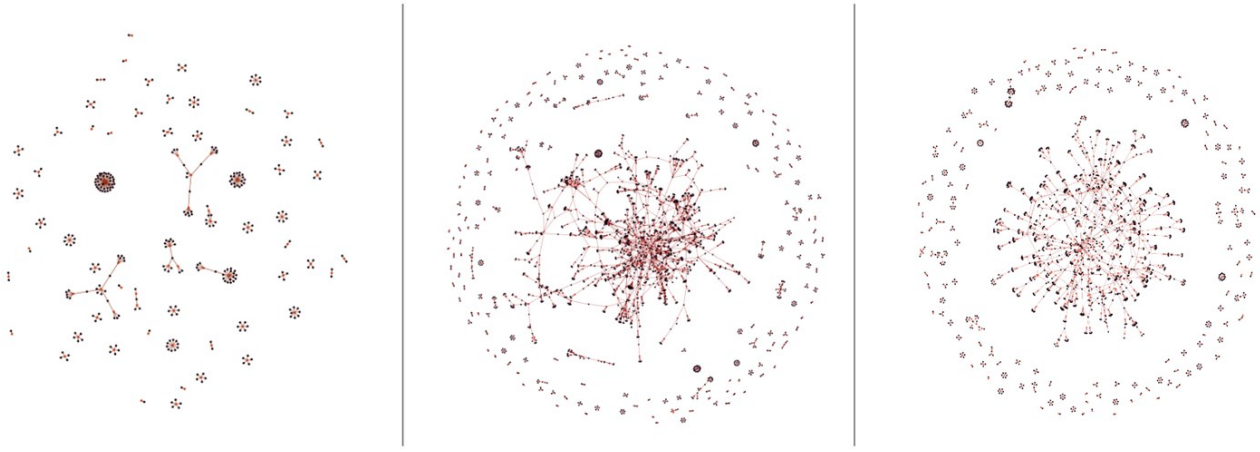

*Figure 1. Two-mode networks of the LIFE-ENV programme in 2007, 2012 and 2017. (Mode 1 – organisations in black colour; Mode 2 – projects in red colour). Source: our elaboration based on LIFE dataset by using GEPHY.*

*Table 2. Four structures of network components in the LIFE-ENV programme from 2007 to 2017. Source: our elaboration based on LIFE dataset.*

| | | ***Structure 1*** **Isolated coordinating beneficiaries** | | ***Structure 2*** **Isolated components** | | ***Structure 3*** **Small components** | | ***Structure 4*** **Giant component** | | ***Entire Network*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mode 1 | Mode 2 | Mode 1 | Mode 2 | Mode 1 | Mode 2 | Mode 1 | Mode 2 | Mode 1 | Mode 2 | Total |
| 2007 | Number | 10 | 10 | 245 | 45 | 87 | 17 | 0 | 0 | 342 | 72 | 414 |
| 2012 | Number | 50 | 50 | 463 | 120 | 171 | 68 | 1209 | 380 | 1064 | 1447 | 2511 |
| 2017 | Number | 28 | 28 | 404 | 104 | 153 | 48 | 973 | 266 | 1558 | 446 | 2004 |
| | | | | | | | | | | | | |
| 2007 | % | 2.92 | 13.89 | 71.64 | 62.50 | 25.44 | 23.61 | 0.00 | 0.00 | 82.61 | 17.39 | 100.00 |
| 2012 | % | 4.70 | 3.46 | 43.52 | 8.29 | 16.07 | 4.70 | 35.71 | 83.55 | 42.37 | 57.63 | 100.00 |
| 2017 | % | 1.80 | 6.28 | 25.93 | 23.32 | 9.82 | 10.76 | 62.45 | 59.64 | 77.74 | 22.26 | 100.00 |

Four different structures have been identified for network components. The first structure refers to "isolated coordinating beneficiaries": they are 10, 50 and 28 respectively for the three years considered and, of course, are connected to the same number of projects. The second structure denotes "isolated components", *i.e.,* a coordinating beneficiary and its associate beneficiaries connected to a single project: their number equals 245 organisations and 45 projects in 2007, 463 organisations and 120 projects in 2012, and 404 organisations and 104 projects in 2017. The third structure represents the initial process of aggregation into multiple "small components" (*e.g.,* beneficiaries connected by more than one project where few coordinating and associate beneficiaries connect with other coordinating or associate beneficiaries). Based on the data, this structure is characterized by a number of small components ranging from a minimum of two projects to a maximum of seven. Specifically, in 2012 the range is between two and five projects, while in 2017 it is between two and seven projects. Moreover, in structure 3 the organisations connected through small components are 87 in total in 2007, 171 in 2012 and 153 in 2017. Finally, the process of aggregation reaches it maximum level with structure four corresponding to a "giant component" (*i.e.,* representing a subset of organisations and projects all linked through bridging ties). In 2007, no giant component is present, while in 2012, the giant component relates 1589 nodes (*i.e.,* 380 projects and 1209 organisations) equivalent to 63.3% of total nodes. In 2017, the structure four connects 1239 nodes (*i.e*., 266 projects and 973 organisations) corresponding to 61.8% of total nodes (see Table 2 for additional data).

*R2. The evolving pattern of relations among organisations and projects and the cohesiveness and density of the sub-programme*

Bridging relations in a given period –*i.e*., the number of relations connecting two or more projects and consequently multiple organisations– are 15 in 2007, 324 in 2012 and 224 in 2017. Thus, the bridging capacity of the entire network (*i.e.,* the number of bridging relations over the total number of relations in the network) equals 4.2% in 2007, 12.6% in 2012 and 11.2% in 2017. On average the value corresponds to 10.9% for the entire period. It can be noted that these relations represent a minority of the total number of possible relations in the networks. Furthermore, the bridging capacity rises substantially from 2007 to 2012 and then slightly reduces in 2017 (Table 3). For a specific year of analysis, the dynamic pattern of existing and ceasing relations has been measured by computing the number of relations referred to each of the three different conditions specified in the Materials and Methods section: entering, permanence and ceasing conditions. The total number of existing relations equals the number of new (*i.e.* entering) relations plus the number of relations that persist (*i.e.* permanence) with reference to a specific year of analysis vis-a-vis previous years. Their number equals 358 in 2007, then shifts to 571 in 2012 when it reaches its maximum value, and finally progressively reduces to 267 in 2017. For relations in the permanence condition, their number of course equals 0 in 2007, then it shifts to 2003 in 2012, reaches its maximum in 2014 (2287), and then progressively reduces to 1737 in 2017. Ceasing relations start to be observed in 2011 and progressively increase in the following years reaching the final value of 483 (the maximum) in 2017 (Table 4). In order to further detail the information provided in Tables 4 and 5 shows how many coordinating and associate beneficiaries maintain or change their formal role in the implementation of LIFE-ENV projects from 2007 to 2017. Of course, the analysis of maintaining or changing patterns has been proposed by observing if a specific organisation maintains or changes its role within two consecutive years. It is possible to observe that coordinating and associate beneficiaries have a very similar dynamic movement during different years. The highest number of both coordinating and associate beneficiaries entering the network is observed between 2011 and 2012. The highest number of coordinating and associate beneficiaries confirming their role in the network is between 2013 and 2014, while the highest number of both coordinating and associate beneficiaries exiting the network is between 2017 and 2018. Specifically, the LIFE-ENV sub-programme started the 2007–2013 programming period with a reduced number of both coordinating and associate beneficiaries entering the programme, then their number has substantially increased till 2011/12. From 2012/13 till recent years, the

level of restructuring of LIFE-ENV has progressively reduced with a decreasing number of both types of beneficiaries entering the sub-programme, which has to be combined with an increasing number of both coordinating and associate beneficiaries leaving the programme. Moreover, from 2014/2015 till recent years, the number of beneficiaries confirming their role has progressively reduced. This is probably due to the change of the entire structure of the LIFE programme in the new programming period (2014–2020) with the creation of two new sub-programmes: one for the environment and the other for climate action. Of course, such a change could have meant that in the new programming period, projects can split into different segments, while they firstly belong only to LIFE + Environmental policy and governance programme.

*Table 3. Relations in the LIFE-ENV programme from 2007 to 2017. Source: our elaboration based on LIFE dataset.*

| *Relations* | ***2007*** | ***2008*** | ***2009*** | ***2010*** | ***2011*** | ***2012*** | ***2013*** | ***2014*** | ***2015*** | ***2016*** | ***2017*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| From 0 to 1 | 327 | 608 | 921 | 1132 | 1373 | 1567 | 1625 | 1562 | 1493 | 1411 | 1332 |
| From 2 to 4 | 15 | 56 | 121 | 188 | 242 | 280 | 292 | 265 | 243 | 225 | 197 |
| From 5 to 10 | 0 | 4 | 11 | 17 | 23 | 35 | 45 | 43 | 36 | 27 | 23 |
| From 11 to 20 | 0 | 0 | 1 | 2 | 5 | 8 | 6 | 4 | 5 | 4 | 3 |
| From 21 to 30 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 1 |
| Total number of relations | 358 | 758 | 1276 | 1698 | 2147 | 2574 | 2725 | 2553 | 2388 | 2220 | 2004 |
| Bridging relations | 15 | 60 | 133 | 207 | 271 | 324 | 345 | 314 | 286 | 258 | 224 |
| Percentage of bridging relations over total relations | 4.19% | 7.92% | 10.42% | 12.19% | 12.62% | 12.59% | 12.66% | 12.30% | 11.98% | 11.62% | 11.18% |

*Table 4. Existing and ceasing relations in the LIFE-ENV programme from 2007 to 2017. Source: our elaboration based on LIFE dataset.*

| | | ***2007*** | ***2008*** | ***2009*** | ***2010*** | ***2011*** | ***2012*** | ***2013*** | ***2014*** | ***2015*** | ***2016*** | ***2017*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing relations: | Number | 358 | 758 | 1276 | 1698 | 2147 | 2574 | 2725 | 2553 | 2388 | 2220 | 2004 |
| (a) *Entering* | Number | 358 | 400 | 518 | 422 | 458 | 571 | 513 | 267 | 284 | 311 | 267 |
| (b) *Permanence* | Number | 0 | 358 | 758 | 1276 | 1689 | 2003 | 2212 | 2286 | 2104 | 1909 | 1737 |
| Ceasing relations | Number | 0 | 0 | 0 | 0 | 9 | 144 | 362 | 439 | 449 | 479 | 483 |
| | | | | | | | | | | | | |
| Existing relations: | % | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| (a) *Entering* | % | 100 | 53 | 41 | 25 | 21 | 22 | 19 | 10 | 12 | 14 | 13 |
| (b) *Permanence* | % | 0 | 47 | 59 | 75 | 79 | 78 | 81 | 90 | 88 | 86 | 87 |

*Table 5. Passages in role in the LIFE-ENV programme from 2007 to 2017. Source: our elaboration based on LIFE dataset.*

| | *2007/08* | *2008/09* | *2009/10* | *2010/11* | *2011/12* | *2012/13* | *2013/14* | *2014/15* | *2015/16* | *2016/17* | *2017/18* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C→C | 72 | 171 | 287 | 386 | 473 | 540 | 567 | 520 | 451 | 393 | 311 |
| A→A | 286 | 587 | 989 | 1303 | 1530 | 1672 | 1719 | 1584 | 1458 | 1344 | 1147 |
| C→0 | 0 | 0 | 0 | 4 | 26 | 80 | 101 | 102 | 125 | 120 | 137 |
| A→0 | 0 | 0 | 0 | 5 | 118 | 282 | 338 | 347 | 354 | 363 | 409 |
| 0→C | 99 | 116 | 103 | 113 | 147 | 128 | 55 | 56 | 62 | 55 | 0 |
| 0→A | 301 | 402 | 319 | 345 | 424 | 385 | 212 | 228 | 249 | 212 | 0 |
| C→A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A→C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0→0 | 3611 | 3093 | 2671 | 2213 | 1651 | 1282 | 1377 | 1532 | 1670 | 1882 | 2365 |
| *Total organisations* | 4369 | 4369 | 4369 | 4369 | 4369 | 4369 | 4369 | 4369 | 4369 | 4369 | 4369 |

Figure 2 represents the density computed by using the formula of Borgatti and Everett (1997) for a two-mode network. Data on the eleven networks show a decreasing density from 2007 to 2013, with a limited increase from 2014 to 2017 which refers to the new EU programming period. Nevertheless, the values of density are very low, ranging between 0.0042 in 2007 and 0.0010 in 2017. This means that in 2007 the existing relations equal 0.4% of all possible relations in the network, while in 2017 this descends to 0.1%, attesting to a very limited cohesiveness of the networks. Of course, if we consider that the LIFE-ENV Programme has a European dimension this value can be expected. Figure 3 presents the global clustering coefficient of the LIFE-ENV networks, which doesn't follow a homogenous path: initially, a rising trend is observed till 2012, although with a temporary decline in 2010, consequently, there is a decreasing pattern from 2012 to 2016, and finally, a very limited recovery in 2017.

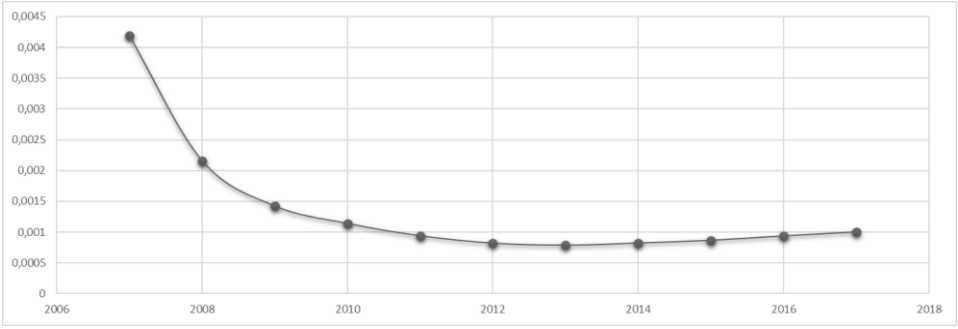


*Figure 2. Density in the LIFE-ENV networks from 2007 to 2017. Source: our elaboration based on LIFE dataset.*

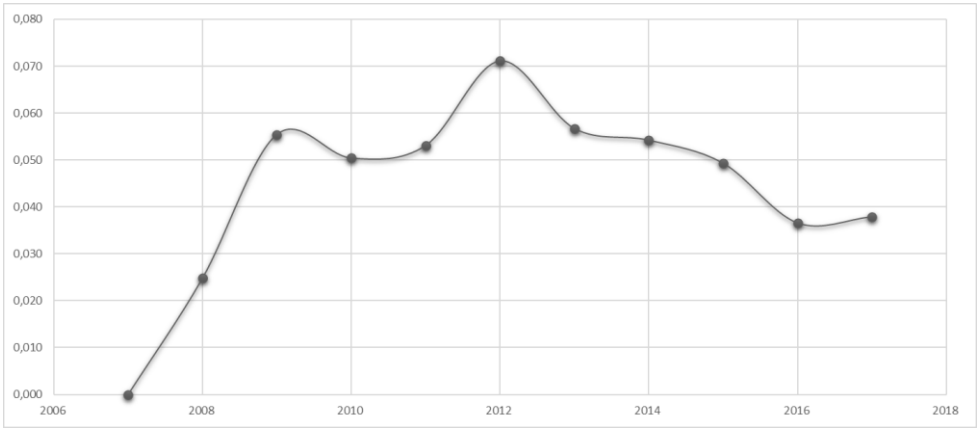


*Figure 3. Clustering coefficient of the LIFE-ENV networks trend from 2007 to 2017. Source: our elaboration based on Tnet package (R software).*

*R3. Betweenness and degree centrality of the sub-programme*

Figure 4 and Table 6 report the graphical representation and statistics for the normalised average betweenness centrality. The measure of centrality reveals a nonlinear pattern, which is characterised by a sequence of increasing and decreasing trends over the eleven years. Values of the centrality measure are in general very low: the highest is 0.00189 in 2008, while the lowest corresponds to 0.00009 in 2017, with an overall average value for the entire period considered of 0.0059.

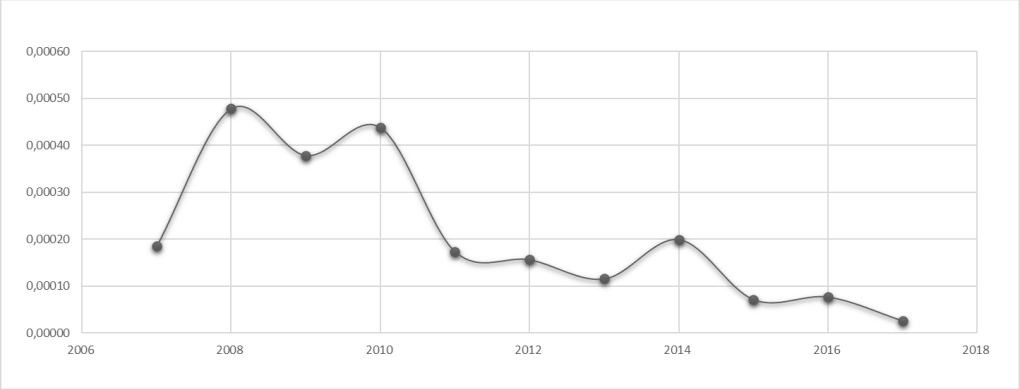


*Figure 4. Average normalised betweenness centrality from 2007 to 2017. Source: our elaboration based on UCINET®.*

*Table 6. Normalised average betweenness centrality in the LIFE-ENV programme from 2007 to 2017. Source: our elaboration based on LIFE dataset.*

| | ***2007*** | ***2008*** | ***2009*** | ***2010*** | ***2011*** |
|---|---|---|---|---|---|
| *Min* | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| *Max* | 0.00569 | 0.01142 | 0.01283 | 0.01028 | 0.00888 |
| *Average* | 0.00095 | 0.00189 | 0.00139 | 0.00150 | 0.00057 |
| *Standard Deviation* | 0.00148 | 0.00281 | 0.00227 | 0.00201 | 0.00110 |
| *Organizations with a positive betweenness* | 73 | 169 | 287 | 390 | 498 |
| *Total organisations* | 342 | 668 | 1054 | 1339 | 1643 |
| *% of organisations with a positive betweenness* | 21.35 | 25.30 | 27.23 | 29.13 | 30.31 |

| | ***2012*** | ***2013*** | ***2014*** | ***2015*** | ***2016*** | ***2017*** |
|---|---|---|---|---|---|---|
| *Min* | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| *Max* | 0.01579 | 0.00579 | 0.01229 | 0.01096 | 0.00722 | 0.00219 |
| *Average* | 0.00048 | 0.00034 | 0.00060 | 0.00022 | 0.00025 | 0.00009 |
| *Standard Deviation* | 0.00137 | 0.00083 | 0.00144 | 0.00086 | 0.00074 | 0.00021 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Organizations with a positive betweenness* | 619 | 665 | 620 | 575 | 511 | 448 |
| *Total organisations* | 1891 | 1970 | 1876 | 1778 | 1668 | 1556 |
| *% of organisations with a positive betweenness* | 32.73 | 33.76 | 33.05 | 32.34 | 30.64 | 28.79 |

In 2007, 21.3% of organisations have a positive value in betweenness centrality characterised by a relatively high value of the measure if compared to the following years (0.00095). Subsequently, in 2013, the LIFE-ENV programme reaches the highest number of organisations (33.8%) with a positive betweenness centrality, but, at the same time, the statistic has a very low value (0.00034). In other words, in 2013 more organisations act as intermediary organisations or brokers, but their brokerage strength is substantially reduced. In 2017 fewer organisations (28.8%) have a positive betweenness centrality, but with the lowest value ever seen (0.0009).

Table 7 shows organisations characterised by the five highest values of betweenness centrality in 2007, 2012 and 2017, categorised by country and type of organisation in accordance with the LIFE classification. By considering the total figures over the 11 years considered for the aims of this study, research institutions represent 27.3% of the selected 55 organisations endowed with highest values of betweenness centrality, while universities equal 23.6%: the two categories together reach a total value of 50.9%. International enterprises and foundations also play an important role: they represent 14.6% and 12.7% of the total organisations respectively. Other organisations include regional public authorities (7.3%); small and medium enterprises (5.4%), large enterprises (1.8%) and local public authorities (1.8%). These central actors are mainly from the South of Europe, specifically Spain (34.5%), Italy (27.3%), and Greece (12.7%). Organisations from these three countries represent 74.5% of total organisations showing the 5 highest values in betweenness centrality.

*Table 7. LIFE-ENV programme (2007, 2012, 2017). Organisations with the five highest values in betweenness centrality measure. Source: our elaboration based on GEPHY.*

| | ***id*** | ***Label*** | ***Country*** | ***Type*** | ***Betweenness*** | ***Degree*** |
|---|---|---|---|---|---|---|
| ***2007*** | 72 | Regione Marche | Italy | Regional Authority | 0.005693 | 0.013889 |
| | 23 | University of Athens National Technical (NTUA) | Greece | University | 0.005110 | 0.013889 |
| | 106 | Centro Tecnológico del Mar. Fundación CETMAR | Spain | Foundation | 0.004864 | 0.013889 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 51 | Coordinamento Agende 21 Locali Italiane | Italy | Foundation | 0.004433 | 0.027778 |
| | 68 | ARPA Emilia-Romagna | Italy | Regional Authority | 0.004424 | 0.013889 |
| ***2012*** | 3754 | Agrifood Research Finland MTT | Finland | Research Institute | 0.015791 | 0.006452 |
| | 327 | University of Torino | Italy | University | 0.012031 | 0.008065 |
| | 3746 | Vapo | Finland | International enterprise | 0.011900 | 0.001613 |
| | 474 | Hellenic Agricultural Organisation "DEMETER" | Greece | Research Institute | 0.011539 | 0.008065 |
| | 23 | University of Athens National Technical (NTUA) | Greece | University | 0.010555 | 0.027419 |
| ***2017*** | 803 | Politecnico di Milano | Italy | University | 0.002193 | 0.008929 |
| | 805 | University Cattolica del Sacro Cuore Milano | Italy | University | 0.001751 | 0.006696 |
| | 958 | Foundation CTM CENTRE TECNOLOGIC | Spain | Foundation | 0.001665 | 0.013393 |
| | 526 | AGC Glass Europe S.A. | Belgium | International enterprise | 0.000999 | 0.004464 |
| | 918 | Lyonnaise Des Eaux France | France | Large Enterprise | 0.000946 | 0.006696 |

The normalised average betweenness centrality refers to the brokerage capacity of intermediary organisations in the entire European network. In order to add to this information, Figure 5 shows the normalised average degree centrality focusing on the local structure around the node by evidencing its level of influence in the surroundings. The statistic decreases from 2007 to 2013 and then starts to slowly increase in the last three years. By comparing the five highest values of betweenness centrality in relation to the previously selected 55 organizations which are used here as a sample, with their degree centrality values it is possible to observe four different patterns in which an organisation could be included: (i) a high degree centrality (high local influence) but a relatively lower betweenness centrality; (ii) a low degree centrality (low local influence) but a high betweenness centrality; (iii) a high degree centrality (high local influence) and a high betweenness centrality; and (iv) a low degree centrality (low local influence) and a relatively low betweenness centrality.

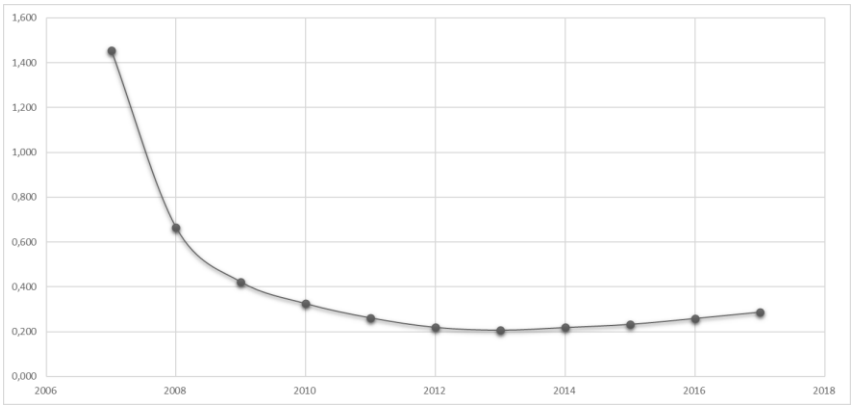


*Figure 5. Normalised Average Degree from 2007 to 2017. Source: our elaboration based on UCINET®.*

*R4. Transnational cooperation among organisations in different European countries of the sub-programme*

The LIFE Programme database allows distinguishing between beneficiaries, both coordinating and associate beneficiaries, based on their country. Thus, it is possible to identify countries that have been funded more often than others, and the extent of transnational cooperation determined thanks to LIFE-ENV sub-programme. Southern European countries are more funded than others, and in particular in 2014 and 2015, these countries have benefitted from more than one-third of the total Programme budget (European Commission, 2018). In the creation of partnerships, the LIFE programme promotes transnationality, thanks to synergies among organisations from different countries. To understand how organisations in different countries relate to one another, we opted for a graphical representation in relation to 2007, 2012 and 2017. Figure 6 illustrates which countries form trans-boundary partnerships and depicts which countries tend to create more synergies with other countries, and, conversely, it reveals the opposite pattern. Results show that EU countries have a different intensity of relations.

*Figure 6. Geographical relations among LIFE-ENV projects (2007–2017). Source: own elaboration based on GEPHY ® - Map of countries layout.*

It is possible to note that countries like Italy, Spain and Belgium tend to create ties with many other countries in both the North and South of Europe. Apart from these three countries, in general terms organisations tend to relate especially with other organisations operating in the same geographical area (*e.g.* Greek organisations tends to relate with organisations based in other South-European countries, while Swedish organisations tend to relate with organisations based in other North-European countries). Finally, countries that recently joined the EU (*i.e.,* the East-European countries) have a limited participation in transnational cooperation.

**Discussions and conclusions**

This exploratory study has analysed to what extent the priority area Environment and Resource Efficiency of the LIFE-ENV sub-programme has facilitated the emergence and dynamic evolution of intermediary organisations supporting environmental initiatives in the framework of the CEG and, specifically, NG theoretical discussion. In particular, the study has analysed the structures and dynamics of the LIFE-ENV sub-programme in eleven years in order to identify, through SNA, intermediary organisations that have emerged thanks to the financial support offered by the EU. The analysis has focused on the evolving pattern of key statistics (*i.e.,* density, clustering coefficient, betweenness and degree centrality) related to bipartite and dynamic networks. The four key findings are now discussed in light of the scientific literature presented in the introduction, then conclusions are proposed.

*F1. Key finding on structures of network components in the sub-programme*

R1. (in short) From 2007 to 2017, the LIFE-ENV sub-programme has financed 1006 projects which have on average 4.4 relations each with an average budget of 3.1 million euro. Moreover, the LIFE-ENV sub-programme is characterised by four different structures of network components, namely isolated coordinating beneficiary, isolated components, small components and giant components. Of the three graphical representations proposed, the fourth structure –giant component– is present twice (2012 and 2017).

Based on R1, it is possible to state that the LIFE-ENV sub-programme has a structural coherence: in other words, a stable structure over the time, evidencing a not transient feature of the network characterised by the fact that coordinating and associate beneficiaries connect systematically in a standard set of structures of network components. The results point out the changing number of intermediary organisations over time, which allow the formation of environmental collaborations in NG (Bodin, 2017). Moreover, they also clarify in what way intermediary organisations are actually included in different collaboration structures. For an organisation to be part of a specific collaboration structure could, in turn, affect the magnitude of its collaboration success if, as suggested by Sandström and Carlsson (2008), we relate actual network composition to collaboration success. So future studies should verify in the specific case of LIFE-ENV sub-programme if, as Bodin and Crona (2009) suggest, environmental outcomes achieved are related to the participation of an organisation in a specific collaboration structure. Moreover, the participation of a specific organisation in the particular structure of a giant component could determine a greater capacity to reach environmental goals, if compared to its inclusion in the structure of a small or isolated component or coordinating beneficiary. We could thus suppose the presence of a multiplier effect on environmental outcomes achieved, determined by the specific structure the organisation takes part in, of course on the premise of a ceteris paribus condition.

*F2. Key finding on the evolving pattern of relations, and on the cohesiveness and density of sub-programme*

R2. (in short). Bridging relations are on average 10.9% of total relations. Existing relations are based on both entering (30% of existing relations on average) and permanence (70% of existing relations on average) conditions. Ceasing relations start to be observed in 2011 and progressively increase in the following years. The LIFE-ENV programme is not a cohesive network, due to low density values. Moreover, the global clustering coefficient increases till 2012, and then progressively decreases in recent years. So, the tendency to form closed groups characterised by bonding relations appears to be very limited.

Based on R2, it is possible to state that both coordinating and associate beneficiaries have increasingly confirmed their role and the number of bridging relations concerns on average 11% of total ones. These two factors together have determined a better dissemination of information and sharing of knowledge within the network. Conversely, the level of restructuring of the network has progressively reduced, and the number of organisations leaving the system increased. This pattern can probably be attributed to two components: (i)

a frictional dynamic of the network where coordinating beneficiaries enter and leave; (ii) an effect determined by the restructuring of the LIFE programme in the 2014–2020 period. In particular, the creation of a specific sub-programme for climate action has probably pushed some beneficiaries to choose this new opportunity, determining a contraction in projects financed by the original LIFE-ENV programme.

Based on R2, it is also possible to state that the density values observed (*i.e.*, the capacity to aggregate actors) are consistent with the specific features of a European programme where the beneficiaries are spread over 28 countries (now 27) and related to different project topics. As a consequence, densities of both the giant and minor components, in these specific circumstances, are normally reduced. As reported in Buckner and Cruickshank (2008) this particular feature has also been observed in other European programmes. Moreover, if the clustering coefficient can be interpreted as a possible measure of bonding relations among organisations that could prevent future initiatives with other external organisations (Schoon *et al*., 2017), the LIFE-ENV networks attest to very low values (all below 0.08), so it is possible to conclude that bonding relations do not characterise the relations among organisations in the years observed.

The values of density can be interpreted in different ways from the existing literature. Some authors, such as Sandström and Carlsson (2008), observed the relationship between network structure and performance in policy networks, concluding that an increasing density pattern and a differentiation in the type of actors help common efforts in policy networks to be reached. A decreasing density could instead signify the decreasing risk of a possible "collaboration fatigue" which could be present if density continued to increase and organisations participated in multiple projects without terminating other collaborations.

Nevertheless, the emerging results could also support the hypothesis of a declining collective action in the LIFE-ENV sub-programme, which is probably taking place although the data on density are extremely low. In this regard, Schoon (2012) has observed that a declining collective action takes place when the density values are progressively reaching the maximum of 1, which the author typifies as an increasing pattern of new collaborations emerging without others terminating. The two elements together can determine a sort of "*fatigue effect*" in collaborations, putting the network in a critical condition that could undermine the capacity of the collective action to continue. In this case, data on density do not indicate the weariness of collaborations, but the lower level of restructuring and reducing number of organisations involved in the sub-programme (if compared to the initial years) is a phenomenon occurring in LIFE-ENV. Consequently, the

network conditions in which collective action in a wide programme declines require a new hypothesis to be considered. Our hypothesis is that the declining pattern could be attributed to the limited number of bridging relations over total ones. This feature, in huge networks, undermines the capacity to further enlarge the network through new collaborations and, thus, the declining pattern of collective action occurs, precisely because of the low value of density.

*F3. Key finding on betweenness and degree centrality of the sub-programme*

R3. (in short). LIFE-ENV sub-programme has facilitated the emergence of 4855 intermediary organisations, which equals 29.5% of the total number of coordinating and associate beneficiaries involved in the programme in the eleven years considered. Nevertheless, normalised average betweenness centrality measures evidence a very reduced brokerage capacity, especially from 2010 to 2017. Research institutions and universities represent 50.9% of the 55 organisations with the highest 5 values in betweenness centrality. Moreover, organisations from Spain, Italy and Greece represent 74.5% of organisations with the highest values in betweenness centrality.

Based on R3, it is possible to argue that in the LIFE-ENV programme the number of actors that both transmit information between groups and, at the same time, have a high probability of receiving new information and knowledge is quite limited. Values of normalised average betweenness centrality measure attest to a very reduced brokerage capacity of the organisations specifically in relation to networks from 2010 to 2017. This tendency undermines the possibility of coordinating and associate beneficiaries to affect the entire network structure and the dynamics of future collaborations in the environment and resource efficiency strand of the LIFE Programme. This result confirms what R2 and F2 indicated in terms of bridging relations, density and clustering coefficient of the network. Results have also shown that research institutions and universities are the key actors in the brokering role within the network, whereas most projects coordinated by private bodies are situated at the network border or, in the worst case, are isolated. Consequently, a more sustained approach in favour of private enterprises could ensure a higher flow of private funds which, in addition to public ones, could determine multiplier effects on the environment and, thus, support the environmental transition. Moreover, results demonstrate the role of research institutions and universities especially in South-European countries (specifically Spain and Italy) who are relevant actors that spread and disseminate information within the network.

*F4. Key finding on transnational cooperation in the sub-programme*

R4. (in short). Spain and Italy report the highest number of financed projects in the eleven years considered and in 2014 and 2015, these two countries have benefitted from more than one-third of the total Programme budget. Transnational cooperation in the LIFE-ENV sub-programme is characterised by a different intensity of relations: some countries (*i.e.* Italy, Spain and Belgium) implement transnational cooperation with multiple European countries in both the North and South of Europe, while others tend to cluster with countries in the same geographical area, and lastly East European countries have limited participation in transnational cooperation.

Based on R4, it is possible to state that the LIFE-ENV sub-programme constitutes an important financing tool in many South-European countries that normally have limited national and regional funds for tackling environmental challenges (Eder and Kousis, 2001). It could be speculated that, in those countries, European funds would also determine additional positive effects such as improved European project design and management capacity. Moreover, the centrality measures indicate that central actors from Southern Europe are fundamental to the LIFE-ENV sub-programme: if they do not take part in it, then the results in terms of collective actions for the environment would be substantially reduced also in terms of networking efficiency and effectiveness. By acknowledging the interdependence between South-European actors and the LIFE-ENV sub-programme, it is possible to state that LIFE is fundamental for the implementation of environmental actions in Mediterranean countries. But, vice versa, based on the actual environmental governance system, South-European actors are also central to the LIFE-ENV sub-programme and its efficient continuation. Without the Mediterranean actors with a high degree and betweenness centrality, LIFE-ENV would very likely be characterised by smaller project networks and, in the worst case, a separate group of projects limited to national boundaries. This configuration could lead to a substantial risk of less transnational cooperation on the environment, for which, at present, Mediterranean countries perform better in terms of collaborative and network governance as centrality measures attest, and a possible risk of uniformity in interests. If actors do not interact and share their knowledge beyond national borders, then the risk could emerge of a decreasing interest in collaborative joint actions for the environment. On the contrary, transnational cooperation can contribute to enhancing the level of project results and impacts, through the sharing of different beneficiaries' world vision, ways of life, shared values, and ways to deal with environmental

problems based on different geographical contextual conditions. The importance of transnational cooperation in the Mediterranean basin has to be stressed, as it is one of the 35 biodiversity hotspots identified by Conservation International (https://www.conservation.org/How/Pages/Hotspots.aspx). At the same time, among all bioclimatic regions, the Mediterranean appears to be the most vulnerable to global change. Most of this vulnerability is associated to the general atmospheric circulation and the role of water as a limiting resource for Mediterranean ecosystems (Palahi *et al.,* 2008).

**Final remarks, study limitations and recommendations**

As an additional observation with respect to the findings discussed above, it is worth mentioning that SNA, which is at the core of this study, has been demonstrated as a relevant tool for contributing to the analysis of intermediary organisations in the LIFE-ENV sub-programme. Nonetheless, some caveats and limitations should also be taken into account. First of all, the possibility to have access to specific information about every beneficiary involved in the LIFE programme is, at present, limited. In the LIFE programme database, the only information on recipients relates to the summary sheets. However, these sheets have some weaknesses and gaps, in particular related to the associated beneficiaries: there are often some uncertainties about their names, and there is a lack of information on their organisation type. Secondly, other essential information to be used in SNA, as an evaluation tool, is the amount of budget allocated to each beneficiary. Having information on the budget distribution would allow the network to be characterised also from a financial point of view. Moreover, having additional information on who the project co-financiers are as well as the supporting institutions or organisations would allow to both increase the level of transparency and better represent the network of actors involved in the LIFE-ENV sub-programme. For this reason, on the one hand, this study lacks specification on co-financers and donors, therefore results do not refer to these actors and, as a consequence, have to be considered with caution; on the other hand, we recommend that information on budget distribution is made available for further and better exploring the effectiveness of large policy programmes like LIFE-ENV, which invest billions of euros in environment management projects with a limited transparency on financial resources allocation. Lastly, it was not possible to find any quantitative information on outcomes and impacts achieved by LIFE-ENV projects. This information would be essential in future research, in order to measure if CEG and specifically NG is really contributing, and how/to what extent, to an effective change in environmental problems of the EU, and how collaborations

among organisations affect the environmental impacts achieved. Despite these gaps, results from the research can provide some preliminary but still promising inputs as well as research hypotheses for future developments. Future studies could build on these first findings and follow different but complementary research lines. For instance, they could investigate how environmental project outcomes are influenced by the composition of projects' partnerships, among other variables, and how Bayesian random graph models could be applied to the evaluation of the environmental project networks.

**Declarations**

Author contribution statement

Elena Pisani: Conceived and designed the research; Performed the analysis; Analyzed and interpreted the data; Wrote the paper.

Elena Andriollo: Performed the analysis; Analyzed and interpreted the data.

Mauro Masiero, Laura Secco: Contributed to the discussion and conclusions.

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**Competing interest statement**

The authors declare no conflict of interest.

**Additional information**

Data associated with this study has been deposited at https://data.mendeley.com/datasets/p9yxnh3yyd/2 [DOI: 10.17632/p9yxnh3yyd.2].

*The LIFE-ENV 2007–2017 dynamic and bipartite graph. Source: own elaboration based on LIFE dataset.*

The video of the dynamic and bipartite network is available at https://doi.org/10.17632/dpnd3tzhvr.1.

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## Article B

### Intermediary Organizations in Nature Conservation Initiatives: The Case of the EU-Funded LIFE Programme

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**Abstract**

This study aims to identify intermediary organizations active in nature conservation initiatives by adopting a multi-level (ML) and network governance (NG) framework and using Social Network Analysis (SNA). We have identified 256 coordinating beneficiaries and 1,090 associated beneficiaries, connected through 8,310 project relations, and financed through the EU-funded LIFE Programme from 2014 to 2020. Results evidence a central component of the network where organizations from Italy, Spain and the United Kingdom play a central role. In contrast, peripheral components return a framework of partnerships mainly constituted of actors of the same country (68%). Moreover, the characterization by type of actor confirms the widespread implementation of a multi-level governance approach in LIFE-Nature (NAT) projects, evidencing the significant presence of non-governmental organizations and foundations, mainly at a national level, in nature conservation initiatives. Findings reveal that the intermediary capacity of key actors should be further reinforced, particularly toward the promotion of transnational cooperation and cross-sector alliances, by encouraging the involvement of stakeholders operating at the ground level (*i.e.,* provincial and municipal levels).

*Keywords: conservation; nature; projects; European Union; LIFE Programme; network governance; multi-level governance; biodiversity; SNA*

**Introduction**

Alarming pictures regarding the state of nature at the global level [1,2,3] denounce the failure to achieve the internationally agreed objectives for the conservation and protection of species and ecosystems [4,5,6,7,8] with severe consequences for the wellbeing of humanity [9]. For example, the "species leap" that led to the SARS-CoV-2 pandemic is considered one of the most apparent consequences of violating ecosystem integrity [10,11]. It demonstrates how animals, plants and the human health closely interlink with the quality of the environment, a concept included in the One Health approach, which assumes that human, animal, and ecosystems health are interdependent and bound to the health of the ecosystems [12,13].

Due to its multifaceted nature, One Health requires a collaborative, multisectoral, and transdisciplinary approach to working at the local, provincial, regional, national, and global levels [14,15]. Thus, effective environmental initiatives that sustain the health and wellbeing of society require integration between multiple aspects and needs concerning both the social and the ecological context in which they are embedded.

This recognition is at the premises of the Social-Ecological Systems (SES), a concept based on a mutual and reciprocal adaptation process in human-ecosystem co-evolution and, therefore, on the interdependencies between institutions (à la North) and ecosystems [16]. Complex interdependencies between societies and ecosystems [17,18] highlight – among other factors – the importance of collaboration in the management of natural resources, based on multi-participatory approaches usually crossing different temporal and spatial scales [18,19,20].

Addressing complex issues, such as the loss of species and ecosystems [21], requires the participation of multiple actors who exercise synergic actions across different jurisdictional levels. Complex interactions concretize the concept of governance seen as "*the formal and informal rules, rule-making systems, and actor networks at all levels (i.e., local, regional and global) that influence how societies identify, design, and implement conservation actions*" [22] (p.155). Additionally, Bulkelev affirms that environmental decisions would be "*created, constructed, regulated and contested, between, across and among scales*" through networking [23] (p. 876), which is proposed as a suitable approach to guiding decisions and actions toward sustainable development.

The Multi-level governance (MLG) concept emerged in the context of the reform of the EU cohesion policy and within the analysis of the European integration process [24]. It refers to the distribution of power between different levels of administration (vertically) but also between different stakeholders (horizontally), including the private and civil sectors [25]. We define MLG as the interaction between the various actors of the private, governmental, and voluntary sectors, representing the different levels of the jurisdictional scale (*i.e*., the decision-making process) where the local, regional, national, and international levels can be distinguished [21,26,27].

MLG is visible in conservation policies acting at multiple levels, from global agreements (*e.g.,* Convention on Biological Diversity) to European policies (*e.g.,* the Habitats and Birds Directives) to the ones implemented at the national level (*e.g.,* national biodiversity strategy), and declined in regional strategies and local governance frameworks [27,28,29].

Effective collaboration is achieved through a collaborative governance approach that brings benefits from the local to the global scale [30]. Conversely, collaboration could not be considered a panacea solution, as it could lead to conflicts and misalignments between the governance structures and the environment, thus reducing the ability to effectively address environmental problems [31].

Governance structures reflect how different stakeholders are arranged to achieve specific outcomes [32]. In the governance of SES, for example, the structure could range from a strictly hierarchical – a top-down or a bottom-up governance structure – to a governance network, that is a structure supporting stakeholder interaction across multiple geographical jurisdictions, policy sectors, and governance levels [33,34]. Therefore, networks emerge as a relational and organizational tool helpful in improving the quality and effectiveness of the environmental initiatives and supporting the increasing adoption of the governance participatory approaches.

Network governance (NG) reflects vertical and horizontal social relationships and structural arrangements that connect citizens, agencies and organizations, and private sector actors in collaborative efforts to achieve a range of objectives [22,35,36]. Multi-actor network ties connect actors horizontally across a single jurisdictional or political level [22], while multi-level network ties connect actors vertically across multiple administrative and institutional levels [37].

Some significant examples of NG applications in managing natural resources and biodiversity are linked to (i) the analysis of collaborative initiatives in conservation strategies [38,39], (ii) the identification of the key stakeholders and pattern of interactions within the network [40,41], (iii) the analysis of conditions that can facilitate coordination of action and overcome conflicts [42,43].

By observing the structures and dynamics of a social network composition, it is possible to identify central actors, also called intermediary organizations. Intermediary organizations are seen as brokers, negotiators and key actors in disseminating knowledge as well as facilitators of new arrangements in the network [41,43]. Furthermore, intermediary actors may exert influence over others by occupying a strategic position in a social network [30,32].

The European Union (EU), as a supranational and regional organization, is increasingly recognized at the international level as a laboratory of multilateral environmental action, which is based on NG principles and based on the formalized collaboration of Member states in sharing policy tools [44].

The EU supports the MLG approach by promoting transnational cooperation in project partnerships and involving, in various initiatives, partners who differ in legal status and interests, objectives, and backgrounds. The European cooperation concretizes (i) the coordination and involvement of actors from multiple sectors, from the local to the regional and national level [45], and (ii) the promotion of network in policy implementation [46,47].

For example, the new Biodiversity Strategy for 2030 aims to halt biodiversity loss and move towards inclusive and sustainable development, focusing on the restoration of degraded habitats, extending the network of protected areas (PAs), and improving their effective management through improved governance [48,49,50]. In Europe's long-term vision, the Biodiversity Strategy for 2030 aims to restore and adequately protect all ecosystems by 2050, strengthen ecological resilience, and prevent future pandemics [7].

Natura 2000 network constitutes the EU's largest network of protected areas. It is regulated by the Habitats and Birds Directives and represents a fundamental instrument for achieving Biodiversity Strategy objectives for 2030 and, generally, EU environmental objectives. Its aim to safeguard the biodiversity also includes not harmful human activities to species and habitats of European interest [51], and integrating ecological needs with social ones [52,53]. Thus, successful management of Natura 2000 sites requires a network governance

approach to coordinate conservation measures or management plans taken by multiple actors with multiple and specific environmental challenges depending on the natural context where interventions occur [54,55].

To achieve EU strategic objectives, EU programs usually foresee financing projects typically promoted by partnerships of actors directly or indirectly involved in the initiative. This is the case of the EU Programme for the Environment and Climate Action (LIFE), a fund directly managed by the European Commission to protect nature and biodiversity and promote mitigation and adaptation to climate change via bottom-up projects proposed by multi-actors and multi-level partnerships. Through an MLG approach, LIFE objectives are reached by networks of actors, consisting of public, private, and not-for-profit bodies acting at different jurisdictional levels. Through networking, actors can develop innovative techniques, methods, and approaches or diffuse best practices resulting from LIFE projects. By linking initiatives through the exchange of ideas and results from a local context to another one, transnational networks demonstrate an enormous potential to catalyze transformative innovations in sustainability [56]. Following this aspect, our perspective provides a conceptual starting point to explore further the development and dissemination of transformative innovation and transition governance strategies [56].

To date, there is still a minimal understanding of the characteristics of the actors, the multi-level and transversal relationships that bind them, the network structure, and how these factors are related in the network governance approach [57,58].

Despite the advantages of different stakeholders' involvement [59,60], implementing a joint management and governance model is often difficult to realize [61].

The LIFE Programme (2014-2020) and, specifically, LIFE Nature (LIFE-NAT) could be considered a suitable case for analyzing the effectiveness of the network governance for nature conservation and restoration, which involve municipal, provincial, regional, national, and international actors. In particular, LIFE-NAT identifies as priorities:

- Activities to improve the conservation status of habitats and species considered of Communitarian interest,
- Activities for supporting the Natura 2000 network,
- Adoption of integrated approaches to the implementation of priority action frameworks.

LIFE-NAT is a tool for testing and developing new approaches, best practices and innovative solutions that demonstrate the European added value in conservation benefits, replicability, transferability, and trans-national outreach [62].

In this way, achieving objectives at the level of a single funded project and diffusing good practices through networking, from the local to the international scale, contribute to achieving European environmental and transversal macro-objectives.

This study aims at analyzing how multiple actors from different geographical and jurisdictional scales address shared problems related to nature and biodiversity protection through ML and NG approaches. We conducted an exploratory analysis by focusing on all levels of the jurisdictional scale of governance in the different European countries, *i.e.,* municipal, provincial, regional, national, and international. Specifically, we identify intermediary organizations involved and their specific features within the partnerships under LIFE-NAT projects from 2014 to 2020.

Based on these premises, this article addresses the following hypotheses, further detailed through specific research questions:

*Hypothesis 1: The presence of intermediary organizations in governance collaborations, which are characterized by dense connections with multiple nodes, implies a higher density within LIFE-NAT network, promoting cohesiveness in relationships and avoiding binding relationships among actors [32]. Q1) How cohesive is the network of actors of LIFE-NAT projects from 2014 to 2019 at the European level?*

*Hypothesis 2: LIFE-NAT projects support multi-level and multi-actor governance through intermediary organizations connecting with different actors in terms of nationality, type, and jurisdictional level [63,64,65,66,67]. Q2) What is the degree of homophily and heterophily of the LIFE-NAT network?*

*Hypothesis 3: Structural differences in LIFE-NAT networks due to relationships created by intermediary organizations, reflect a different way to implement MLG and NG through LIFE projects [18,32,68,69]. Q3) What structural differences in MLG of LIFE-NAT project networks emerge from 2014 to 2019? What differences are observable between different countries in Europe?*

*Hypothesis 4: Within European policy context, State actors have a prominent role in the transmission of information and dissemination of good practices due to their primary responsibility for nature conservation and management, playing the role of intermediary actors in governance processes [70,71,72]. Q4) To what extent State actors are widespread in the LIFE-NAT network as intermediary actors? Who are those able to catalyze the process of information, transmission, and control? What is their level of influence in the LIFE-NAT network?*

*Hypothesis 5: A higher presence in a social network of non-governmental actors as intermediary organizations [73] is linked to changed relationships between governmental and non-governmental actors in the decision-making and governance processes [74,75]. Q5) To what extent does the LIFE-NAT priority area facilitate the emergence of non-governmental actors as intermediaries?*

Consequently, the article is structured in six sections. After this introduction, the theoretical framework is presented in Section 2, followed by the description of materials and methods (Section 3). Section 4 presents results discussed in depth in Section 5 with research limitations and ideas for future analysis. The article concludes with Section 6 summarizing the final remarks.

**Conceptual framework and proposition**

*Network cohesion (H1)*

The network's cohesion level is an essential characteristic since it measures the extent a network is united instead of being split into separate subgroups [76]. A subgroup can be defined as an entity having significantly more links between its members than those established with non-members [32].

To investigate the effectiveness of ML and NG approaches in LIFE-NAT projects, the statistical measure of "network density" has been used (*i.e.,* the number of existing ties compared to the total number of possible ties). This statistic reflects the network cohesiveness. The higher the level of cohesiveness among diverse actors implementing environmental initiatives around the EU territory, the higher the capacity of LIFE projects to promote effective collaborations (Hypothesis 1).

Several studies support the hypothesis that a higher presence of social ties in networks corresponds to enhanced possibilities for collaboration, communication, and fosters mutual trust. These dynamics would

help avoid conflicts and foster the development of regulations on common natural resources [*e.g.,*77,78,79]. Conversely, the existence of subgroups can be disadvantageous for joint actions to govern common natural resources having consequences on the ML and NG approaches [80]. However, this limitation could be overcome if actors establish bridging links between sub-groups and demonstrate the capacity and motivation to coordinate activities towards a common goal. The formation and maintenance of subgroups in the network allow the exchange of information, *i.e*., a continuous and persistent interaction, between actors with different levels of specialization [81]. The presence of these entities could provide opportunities for a high degree of interaction between similar subgroups, develop different typologies of knowledge in diverse subgroups, and hybridize existing knowledge between different clusters of actors, with implications for the effective governance of natural resources [82].

*Network homophily (H2)*

Sociological literature argues that humans tend toward two divergent points (i) homophily, in which people look for similar people, and (ii) heterophily, in which people look for people who are different [83].

Evidence suggests that individuals prefer to form social ties with people who share their characteristics such as education, race, age, and sex [84,85,86]. This feature corresponds to the homophilic trait of the social network, which is well documented in different circumstances [63,87,88,89,90].

Nevertheless, in its broadest sense, the LIFE Programme aims to catalyze transnational synergies among countries by breaking down barriers to collaboration between the different levels of MLG and among different stakeholders' attributes.

To better understand the transversal dynamics of environmental governance, we've observed if different attributes (*i.e.,* in terms of "nationality" "typology" and "jurisdictional level") represent advantages in the concretization of an MLG within the LIFE-NAT network (Hypothesis 2). To this end, we've used the E-I index [91]. Considering a network of mutually exclusive groups, the E-I index is a social network measure calculated as the number of ties external to the groups minus the number of ties that are internal to the group divided by the total number of ties.

*Multi-level governance (H3)*

Effective coordination and collaborative dynamics within and among groups implementing environmental activities at sub-national levels can support environmental governance on a higher level by promoting the political learning necessary for a legislative change [92]. One of the main objectives of the LIFE Programme is to support the development, implementation, monitoring and enforcement of relevant Union legislation and policy on the environment, including nature and biodiversity by improving governance at all levels, in particular by enhancing the capacities of public and private actors and the involvement of civil society [62]. In this perspective, MLG governance is realized through decentralized models constituted by networks of private and public actors interacting at different geographical and jurisdictional scales. Collaborative relationships are regulated by coordination based on the exchange of resources and trust [66,70]. These models allow replacing hierarchical-based models of a government-type [22,35,36].

The literature proposes two ideal types of MLG called Type I and Type II [93]. Type I follows the federalist model, characterized by a limited number of jurisdictional authorities. Government agreements are displayed on hierarchical levels and arranged on a vertical scale, among which the "international", "national", "regional", "provincial", and "municipal" levels are distinguished. Type II consists of a set of multiple jurisdictional authorities exercising specific competencies. These entities can operate transversely on various territorial scales and have flexible structures to respond to changing governance needs, thus arranging themselves on a horizontal structure.

Hypothesis 3 aims to understand how the transversal relationships between multiple actors involved in environmental governance differ, verifying if they follow Type I or Type II of MLG.

Considering the complex and uncertain nature of the issues concerning the protection of species and ecosystems, we assume that the LIFE-NAT network responds to a Type II of MLG, which reflects a flexible framework of relationships on a horizontal structure [94].

*Intermediate actors (H4)*

The presence of intermediary organizations influences the behaviours of other actors embedded in the MLG networks, constituting new relationships, and reorganizing existing connections vertically and horizontally through bridging links [32,95,96]. These elements allow us to understand why centrality measures are a widely studied phenomenon in network science [97,98]. By occupying specific central positions in the

network, actors can influence others, having priority access to the flow of information, which can prove beneficial in the intermediation process [72,99]. Intermediation processes have implications that go beyond the exchange of information and knowledge. In the long term, they promote the possible dissemination of social values such as trust, support for future actions, adaptability or, on the contrary, the emergence of binding actors who preclude the participation of others in future initiatives. Understanding how the social network can support or hinder many governance initiatives concerning the environment is essential in analyzing the structural characteristics of these networks and, specifically, the characteristics of intermediate actors [74,100].

To this end, a specific research hypothesis focuses on bridging organizations and their control and transmission of information within the network of LIFE-NAT projects. Considering the State's responsibility for the management of protected areas and generally on the implementation of conservation measures [101,102,103], we suppose that the central players in the LIFE-NAT network are State actors although their central role is mediated by other actors (Hypothesis 4).

*Governance vs. government (H5)*

To support an environmental policy aimed at generating effective results and fostering sustainability, the literature suggests two main vital strategies, (i) adapting the spatial scale and level of governance to the environmental problem [104] and (ii) strengthening the participation of non-governmental actors in the decision-making process as well as in the implementation of initiatives [36].

Although for a long time, the term governance was considered synonymous with government [105,106], in recent decades, a widespread consensus emerged in understanding governance as the evolution of Montesquieu's concept of government (*i.e.,* executive power) [106,107].

Governance overcomes the clear distinction between public and private actors [106], valorizing the latter's role in the supply of public goods if organized in the form of horizontal networks through collaborative arrangements [54].

The meaning of collaborative governance [18,108,109] leads us to formulate Hypothesis 5, which focuses on the role of non-state actors in the mediation of relationships among actors. Thus, they behave as brokers and impact the political decision-making process determining a change in the relational setting [43,71,110].

Indeed, as demonstrated by Reimer and Saerbeck's (2017) exploratory analysis, different types of actors - non-governmental organizations and government actors - act as real political entrepreneurs [73].

**Materials and methods**

*Database creation*

This study analyses LIFE-NAT projects through a network approach. Data are organized in three different levels of information:

- project-level, *i.e.,* general, and specific objectives of projects, achieved results, and localization of activities, retrieved from the project website.
- beneficiary level, *i.e.,* nationality, website, type of actor, level of governance, based on the specification of the project website.
- project partners' relationship level, *i.e.,* the direction of the relations among beneficiaries.

The LIFE Project Database makes it possible to access information on projects funded during the LIFE programming period 2014-2020. However, data referring to the year 2020 are not included as they will be published in the first half of 2022. The projects covered by our analysis all belong to the same LIFE programming period (2014-2020) and comply with the same EU regulation (Regulation (EU) N° 1293/2013) [62]. This provides a contract between the parties concerned (namely the Coordinating beneficiary and the European Commission), regulating the co-financing over the years, also in order to maintain the partnerships' composition stable for the duration of the project. As our results confirm, to date, the average duration of a project is around 5,4 years with 26,3% of the projects funded from 2014 to 2020 having been completed. Throughout the duration of the project, the partnership is not subject to governance changes.

The list of selected projects has been exported and organized into two MS Excel spreadsheets. The first one shows the list of projects and includes their general administrative features. Information has been manually obtained by consulting each specific project sheet.

The second MS Excel spreadsheet focuses on data related to the project partnership. For each project, information for each type of beneficiary (Coordinating and Associate beneficiary) has been entered, uniquely identified by the VAT number (abbreviation for Value Added Tax).

Detailed information for each project actor concerned to its country, the level of governance (*i.e.,* international, national, regional, provincial, municipal) and the type of actor. From civil society to local authorities, the LIFE Regulation (Art. 3) does not exclude any type of organization for the selection and co-financing of the project initiative, [62]. Types of beneficiaries refer to the taxonomy proposed by the database of LIFE projects, which includes different categories of actors located in public, private or public-private spheres [54]. Specifically, the following categories have been utilized: international enterprise, large enterprise, mixed enterprise, small and medium-sized enterprise (SME), public enterprise, non-governmental organization-foundation, national authority, regional authority, local authority, park-reserve authority, professional organization, research institute, university, and educational centre.

The level of governance for each actor is highlighted through the following attributes: international, national, regional, provincial, and municipal, as proposed by the scientific literature of MLG [21,111].

For our analysis, we connect through links (*i.e.,* network edges) all organizations participating in the same LIFE-NAT project [110]. Consequently, we associate each project beneficiary with a unique progressive code obtaining the list of "Nodes" constituting the analyzed network.

Subsequently, another MS Excel spreadsheet was created to identify the links among beneficiaries constituting the partnership of each project. The graph ties are considered "not-directional" since two actors shall participate equally in the relationship. For this reason, the type of relationship is considered "undirected", if the flow of information, communications, and, more generally, the "exchange" between the two nodes takes place from both parties [112].

Data collected in the "Nodes" and "Ties" sheets have been imported into the GEPHI software® for graphic and statistical processing.

*Network Analysis*

Social Network Analysis (SNA) is a method for analyzing and visualizing the structural characteristics of a network. [113,114]. The SNA displays social relations through graphs consisting of ties (arcs) connecting individuals (nodes) [115]. This method aid in identifying structures and patterns between project partners [116] and highlights best practice examples for establishing effective conservation partnerships [54,117].

Notably, the SNA approach can reveal the position of each actor participating in the network and its influence, and so it helps to optimize the information flow [22]. GEPHI software® was used to generate network images.

*Quantitative analysis*

Through SNA, the description of different network structural characteristics, such as the number of ties, the network density, and centrality measures, allows for quantitatively describing the network governance supported by LIFE projects analyzed [32].

SNA, through the representation of nodes (*i.e.,* actors) and ties (*i.e.,* the relationships between nodes), help to identify what organizations serve as "bridges" for disconnected actors or can reveal subgroups of actors that are separated from the others [22].

From a methodological point of view, the analysis was structured using different statistical network measures depending on the specific research question.

*Q1) How cohesive is the network of actors of LIFE-NAT projects from 2014 to 2019 at the European level?*

Density is a fundamental network measure, *i.e.*, the total number of ties in a network [118]. This measure expresses the level of saturation of relationships between nodes. In other words, density measures the actual connections between those that could exist, given the number of nodes. The level of network cohesion could be predictive of the ease with which information is transmitted and the condition for the emergence of intermediary actors [55].

*Q2) What is the degree of homophily and heterophily of the network?*

The E-I index [90], comparing internal and external group ties, determines the degree of homophily or heterophily.

A positive value of this index indicates the presence of heterophily, while a negative one indicates homophily. The approximation of the E-I index to +1 means that all relationships result between actors with differentiated attributes (high heterophily). In contrast, a value close to – 1 would indicate that all connections are between subjects with the same attribute, revealing high homophily. If the links are distributed equally, the index will be equal to zero [90].

Considering the E-I index value for "nationality", "type of organization" and "jurisdictional level", it is possible to determine whether actors with homogeneous characteristics are inclined to interact more or if different attributes do not represent obstacles to communication and network collaboration [63].

Characterizing the LIFE-NAT network as homophilic or heterophilic for these characteristics allows us to verify multi-actor and MLG's presence.

*Q3) What are the structural differences in MLG in the LIFE-NAT project networks from 2014 to 2019? What differences are observed between Northern and Southern Europe countries? What are the characteristics that describe such projects?*

GEPHI ® allows manipulating the structure, shape and colours of a graph to simultaneously highlight different attributes within the network, possibly combining different layouts. In this way, a qualitative comparison of the network of actors was possible by varying the attribute.

Using the GEPHI software®, it was possible to obtain the different network structural characteristics, such as the number of ties, the network density, and centrality measures, to achieve the research objectives. It was possible to obtain a graphic representation of the network structure, highlighting central actors. The graph is functional to understand which relationships are facilitated within LIFE-NAT and which European countries are most involved in forming project partnerships for nature conservation.

*Q4) What types of actors catalyze the process of information transmission and control? What is their level of influence in the LIFE-NAT network?*

Through the analysis of betweenness centrality at the level of a single node, it was possible to define the centrality of these nodes and, consequently, understand what characteristics can catalyze the process of transmission and control of information.

Through this measure, we can identify the key actors in the LIFE-NAT network and understand at what jurisdictional level they operate and what type they belong to; in this way, it is possible to enhance their presence in the partnership compositions.

*Q5) To what extent does the LIFE-NAT priority area facilitate the emergence of non-governmental actors as intermediary organizations in the network?*

As statistical network's measures, the degree and betweenness centrality indices help investigate whether the LIFE-NAT network favours the emergence of "non-governmental actors" as intermediaries [119,120].

The degree of a node is the total number of ties it possesses, regardless of its direction. It measures the importance of a node based on the number of neighbouring nodes. It indicates its potential in communication activity and, more generally, to pass whatever is flowing in the network [119]. However, a node with a high degree value but located in a peripherical area of the network has a limited capacity to act as an intermediary actor [120]. Intermediate actors are identified using the statistical measure of betweenness centrality. Betweenness centrality is considered a measure of the influence that a node exerts on the entire network based on its ability to establish bridges between clusters of nodes which allows the functioning of the entire network [120]. An organization that acts as an intermediary appears decisive in implementing European environmental policies on different jurisdictional levels through LIFE projects.

Concerning Q5, the degree centrality measure helps identify the organizations linked with many participants within LIFE-NAT projects (*e.g.,* their higher level of expertise in applied conservation projects). In contrast, the betweenness centrality indicates key actors in the network's communication flow within LIFE-NAT partnerships [121].

**Results**

*Quantitative Results*

*R1. Cohesiveness*

The density index is calculated using GEPHI®. Density equals 0.009, which means that the existing relationships are 0.9% of all possible relationships if all the actors were connected. This value reveals a lack of cohesion in the network; however, it can be expected if the European dimension of the LIFE-NAT is considered.

*R2. Homophily*

The homophily index was calculated by considering the total network relationships (8,310) for each attribute, *i.e.*, "nationality", "typology", and "jurisdictional level". The E-I index value for the "nationality" was -0.2880,

revealing homophily for this attribute and, therefore, the tendency of actors belonging to the same country to interact mainly with each other (Table 1).

| | Ties by "nationality" (n°) | Ties by "typology" (n°) | Ties by "jurisdictional level" (n°) |
|---|---|---|---|
| **IL** | 5352 | 1820 | 3438 |
| **EL** | 2958 | 6490 | 4872 |
| **E-I index** | - 0,2880 | + 0,5619 | + 0,1725 |

*Table 1. Values of IL, EL and E-I index observed for the different attributes considered (Source: our elaboration of the LIFE dataset).*

The "typology" and "jurisdictional level" categories show the involvement of heterogeneous actors in LIFE-NAT projects. The E-I-index values calculated for these two attributes were +0.5619 and +0.1725. Based on these results, it is possible to confirm heterophily in the jurisdictional scale and typology of nodes.

The EL (*i.e*., the number of external links) for "typology" resulted in 6490 and exceeded the IL (*i.e.,* the number of internal links) (1820), so it is possible to state that the collaboration between actors who belong to different types is well-established in LIFE-NAT projects. The network is distinctly heterophilic for this attribute, demonstrating the role of the LIFE Programme in acting as a facilitator in removing the barriers to collaboration between the different typologies of actors.

Collaborations between actors at different levels of governance are not sufficient to characterize the LIFE-NAT network as heterophilic, given that the EL (4872) exceed IL (3438) relationships, evidencing that the network is slightly heterophil regarding the jurisdictional level of actors. In conclusion, based on results indicating homophily in the nationality of actors, it can be understood how the network realized within LIFE-NAT projects expresses the tendency of actors to collaborate more intensively with those having the same nationality. Conversely, these actors belong to different typologies.

*R3. Structural differences in multi-level network governance*

From the general structure of the graph, a significant central component and peripheral components can be observed. It is possible to see how the countries with the most significant number of LIFE projects – including

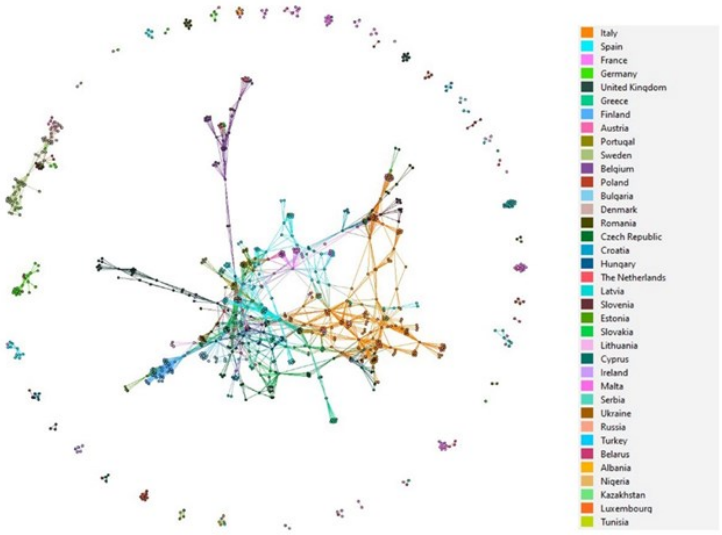
Italy, Spain, the United Kingdom, France, Bulgaria, and Germany – constitute a connected structure at the centre of the network (Figure 1a).

The marginal area of the network, on the other hand, appears to be dotted with partnerships mainly constituted by organizations of the same nationality. Out of 47 peripheral structures, 32 (68%) are composed of actors from the same nation. Conversely, 15 (32%) of these satellite structures are made up of partnerships from neighbouring countries.

Considering the characterization of nodes and ties by type of actor, the analysis of the central structure of the entire network reveals the strong presence of non-governmental organizations (NGOs), transversal to several countries and widespread in the United Kingdom, Belgium, and the Czech Republic. Italy, the country to have presented more projects under LIFE-NAT from 2014 to 2019, shows a heterogeneous network that stands out for the role of research institutions, park-reserve authorities, and universities (Figure 1b).

Regarding the jurisdictional level, the graph confirms the predominance of organizations working at the national level (Figure 1c).

Observing the central structure of the entire network, this level is particularly evident for countries such as Italy, Germany, Belgium, and the United Kingdom. In this last case, regional actors are also well represented. In the periphery of the network, mainly focusing on collaborations between Sweden, Germany, Denmark, and Belgium, it can be observed that for Denmark, the relations mainly involve actors at the municipal level. In contrast, for Sweden, the national, regional, and provincial levels of governance are equally represented.


Italy
Spain
France
Germany
United Kingdom
Greece
Finland
Austria
Portugal
Sweden
Belgium
Poland
Bulgaria
Denmark
Romania
Czech Republic
Croatia
Hungary
The Netherlands
Latvia
Slovenia
Estonia
Slovakia
Lithuania
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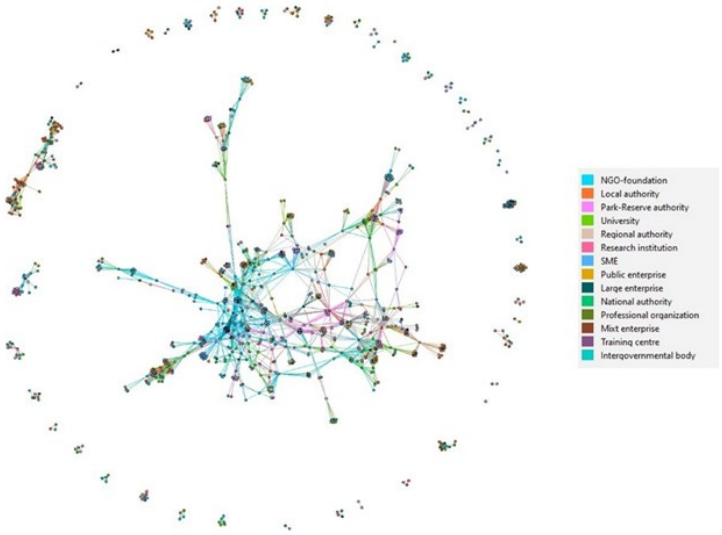
NGO-foundation
Local authority
Park-Reserve authority
University
Regional authority
Research institution
SME
Public enterprise
Large enterprise
National authority
Professional organization
Mixt enterprise
Training centre
Intergovernmental body

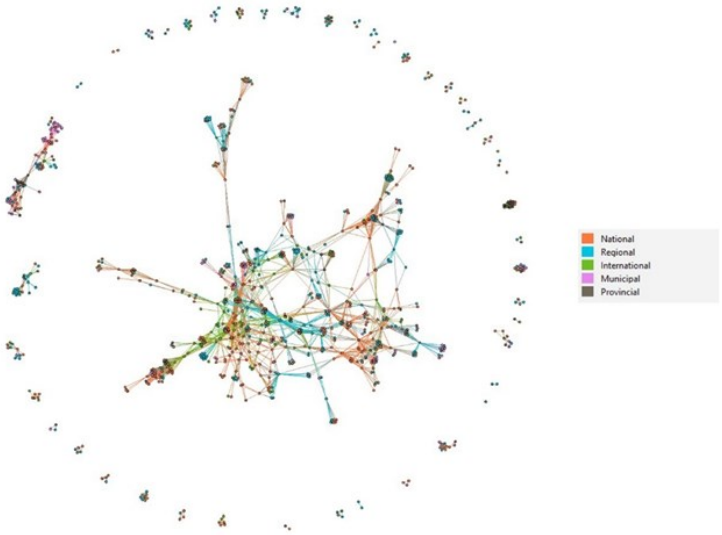
National
Regional
International
Municipal
Provincial

*Figure 1. Graphic representation of the network formed by LIFE-NAT in the period 2014-2019. The colors refer to the nationality (1a), type (1b) and jurisdictional level (1c) of the actors (Source: GEPHI® elabora-tion of the LIFE dataset).*

*R4. Types of intermediary organizations*

Within the LIFE-NAT network, the average value of the degree centrality is equal to 8,290. The value means that, on average, each actor has eight relationships with other project actors, with a minimum value of 1 (if we do not consider projects with a single actor) and a maximum value of 53.

Out of a total of 972 organizations

- Four organizations (0.4%) have a null degree value,
- 840 organizations (86.4%) have a value between 1 and 15,
- 113 organizations (11.6%) between 16 and 30, and
- 15 organizations (1.6%) between 31 and 53.

Considering this last class, NGOs constitute 40%, regional authorities represent 26.6%, research institutes represent 13.3%, and the remaining 20% is distributed equally by public and private companies and national authorities. The jurisdictional level for this class of actors is predominantly national (40%), international (33.3%) and regional (26.6%). Central actors come mainly from the countries of the Mediterranean basin, namely Spain, Italy and Greece (53%), followed by actors coming from Eastern Europe (27%). In comparison, the actors of Northern Europe are less represented (20%).

The organization with the highest degree index is the NGO Sociedad Española de Ornitología (SEO). In the second place, in the ranking of the five organizations with the highest degree, there is another NGO, the Bulgarian Society for the Protection of Birds (BSPB), followed by the Spanish Regional Authority Junta de Extremadura, Legambiente Onlus (Italy) and the Finnish public company Metsähallitus Parks & Wildlife Finland (MHPWF) (Table 2).

As emerged from the representation of the network structure, the nodes that are central in the network refer to actors from Italy, Spain, France, Finland, Belgium, and Greece. The national, international, and

regional levels stand out for the jurisdictional scale. In contrast, the central nodes are constituted chiefly by NGOs, research institutes, and regional authorities for typology.

| Id | Label | Country | Type | Jurisditional governance scale | Degree | Betweenness |
|---|---|---|---|---|---|---|
| **282** | Sociedad Española de Ornitología (SEO) | Spain | NGO-foundation | National | 53 | 0.074316 |
| **95** | Bulgarian Society for the Protection of Birds (BSPB) | Bulgaria | NGO-foundation | International | 51 | 0.042237 |
| **340** | Junta de Extremadura | Spain | Regional authority | Regional | 47 | 0.029317 |
| **633** | Legambiente Onlus | Italy | NGO-foundation | National | 45 | 0.05317 |
| **356** | Metsähallitus Parks & Wildlife Finland (MHPWF) | Finland | Public enterprise | International | 44 | 0.042942 |

*Table 2. The five organizations with the highest degree index (Source: our elaboration of the LIFE dataset).*

Analyzing the network of LIFE-NAT projects, the values of betweenness centrality have generally proved to be very low: only 186 (19%) out of 972 organizations have a positive value of betweenness centrality, among which the highest stands at 0.12907 while the lowest is 0.000004. NGOs (27%), universities (13.4%) and regional authorities (11.3%) together make up 51.7% of the categories of actors with a positive betweenness centrality. The level of governance for these actors was predominantly national (38.3%), followed by international (35%) and regional (20.5%). Central actors come mainly from the countries of the Mediterranean basin (46.1%), followed by actors from the countries of Northern Europe (28.8%), while the actors from Eastern Europe represent the minority (17.2%). NGOs entirely constitute the ranking of the five organizations with the highest betweenness centrality index; Hellenic Ornithological Society (Greece) came first, followed by Sociedad Española de Ornitología (Spain), Ligue pour la Protection des Oiseaux (France), Natagora Asbl (Belgium) and Legambiente Onlus (Italy) (Table 3).

| Id | Label | Country | Type | Jurisditional governance scale | Degree | Betweenness |
|---|---|---|---|---|---|---|
| **227** | Hellenic Ornithological Society | Greece | NGO-foundation | International | 37 | 0.129066 |
| **282** | Sociedad Española de Ornitología (SEO) | Spain | NGO-foundation | National | 53 | 0.074316 |
| **439** | Ligue pour la Protection des Oiseaux | France | NGO-foundation | National | 29 | 0.07207 |
| **70** | Natagora Asbl | Belgium | NGO-foundation | Regional | 24 | 0.054413 |
| **633** | Legambiente Onlus | Italy | NGO-foundation | National | 45 | 0.05317 |

*Table 3. The five organizations with the highest betweenness centrality index (Source: our elaboration of the LIFE dataset).*

*R5. Characterization of partnership composition*

From 2014 to 2019, 256 coordinating beneficiaries and 1090 associated beneficiaries were involved through the constitution of 8310 relations. The average number of actors in a LIFE-NAT project partnership results in 5.25, while the average number of associated beneficiary actors in the project partnership is 4.25. Most of the coordinating beneficiaries are represented by NGOs and foundations (32.81%), followed by public bodies such as park reserve authorities (11.71%), local authorities (10.54%), national authorities (9.37%) and universities (8.98%) (Figure 2).

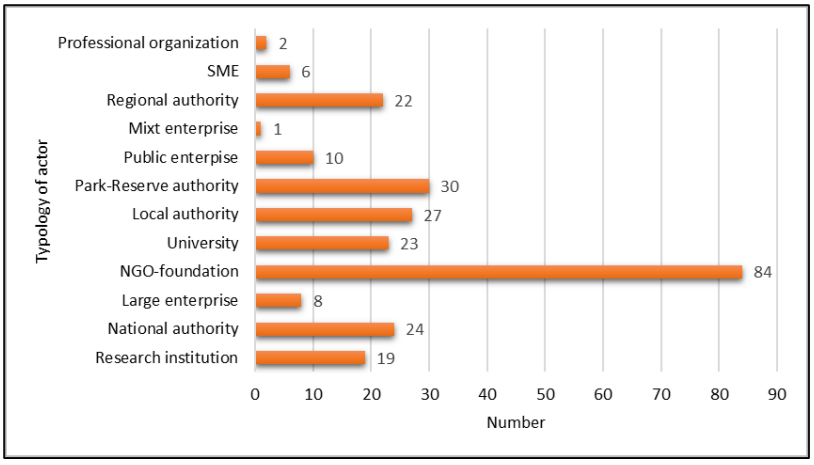


*Figure 2. Typology of Coordinating beneficiaries for LIFE-NAT (2014-2019) (Source: our elaboration of the LIFE dataset).*

Regarding the associated beneficiaries, most of them are represented by NGOs and foundations (24.04%), followed by public bodies such as park reserve authorities (10.37%), local authorities (10.37%), regional authorities (10.37%) and universities (9.54%). Considering all the beneficiaries, the number of actors belonging to NGOs and foundations (25.71%) stands out, followed by actors from public bodies such as the park reserve authorities (10.62%), local authorities (12.84%), regional authorities (10.03%) and universities (9.44%) (Figure 3).

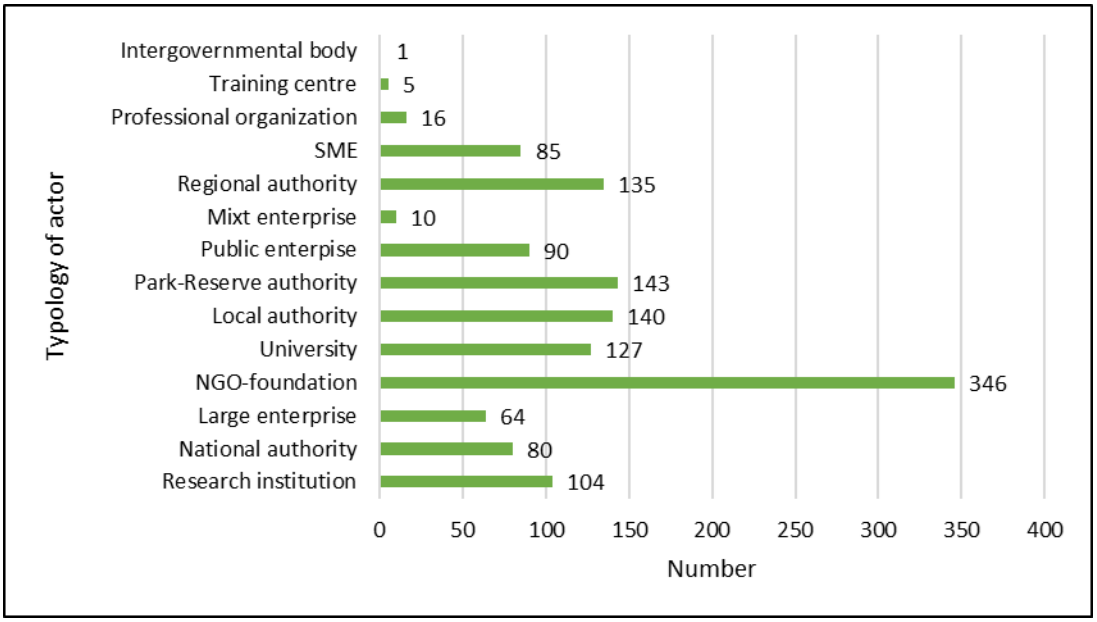


*Figure 3. Typology of the overall beneficiaries for LIFE-NAT (2014-2019) (Source: our elaboration of the LIFE dataset).*

Regarding the jurisdictional level for coordinating beneficiaries (256), it emerges that the analyzed network is dominated by actors at the international level (34%), followed by the national (31%), regional (26%), provincial (5%), and the municipal (4%) one.

Regarding the jurisdictional level for the associated beneficiaries (1090), it emerges that the network is dominated by actors at the national level (47%), followed by regional (29%), international (12%), municipal (7%), and provincial (5%) levels.

Considering the entire network of beneficiaries, the predominance of actors at the national level (43.68%) emerges, followed by the regional (28.38%), international (16.49%), and municipal (6.68%), and provincial (4.75%) one (Table 4).

| | | |
|---|---|---|
| **Municipal** | 90 | 7% |
| **Provincial** | 64 | 5% |
| **Regional** | 382 | 28% |
| **National** | 588 | 44% |
| **International** | 222 | 16% |

*Table 4. Actors benefiting from the LIFE-NAT (2014-2019) described by jurisdictional level (Source: our elaboration of the LIFE dataset).*

The total number of organizations that benefit from co-financing through LIFE-NAT projects amounts to 1346. 374 (27.8%) access to funding more than once during the 2014-2019 programming period, covering different roles. In the six years considered, the countries benefitting most from participation in the LIFE-NAT priority sector are in order: Italy (46 projects), Spain (25), followed by the United Kingdom (19), France and Bulgaria (15) and Germany (14).

**Discussion**

This study allows us to deepen how multiple actors from different geographical and jurisdictional scales address shared environmental problems through MLG and NG approaches. Below, the evidence from the analysis will be discussed concerning each research question.

*Q1) How cohesive is the network of actors of LIFE-NAT projects from 2014 to 2019 at the European level?*

The density value observed is coherent if we consider the spread of LIFE beneficiaries in 28 countries and the variety of project types implemented in heterogeneous areas of the EU. A low network density index has also been observed in other European programmes, as Buckner and Cruickshank (2008) reported and can be traced back to barriers to establishing collaborations, as evidenced by choice of project partners predominantly within national boundaries [122].

This sort of "fatigue" in establishing collaborative relationships can have multiple concomitant causes, such as language barriers, diverse national legislations, heterogeneity of environmental conditions, as well as a diverse historical and cultural background that characterizes the different European countries [123,124,125].

This "fatigue" appears evident in the peripheral network region, where most of the partnerships are constituted by beneficiaries from the same country.

On the contrary, the central part of the network refers to partnerships from different countries that have submitted more projects within LIFE-NAT (Italy, Spain, France, Germany, and the United Kingdom). It is possible to highlight how most of these countries are neighbouring Member states. Therefore, even if, in general, the network does not show cohesion, it is possible to appreciate the efforts of neighbouring countries in southern Europe to promote concrete actions aimed at nature conservation via LIFE-NAT.

As reported by the literature, the density is related to trust among actors and collective action [126,127,128]. Sandström and Carlsson (2008), for instance, relate the network density and the differentiation in actors' composition to success in collaboration achieved through joint action efforts [128]. Although the trend in network density over time does not constitute the subject of our investigation, we hypothesize that the LIFE-NAT network could suffer from a lack of joint collective action if the bridging relations do not increase in the coming years. The same hypothesis has been raised for the LIFE-ENV sub-programme by Pisani *et al.* (2020) [129].

Density could play a crucial role in different aspects of learning [55]. In a less dense network, information can become distorted when transmitted via many different actors. Moreover, the exchange of ideas and arguments, known as the "deliberation" process, is scarce [55,130,131].

While it is true that the level of cohesion does not distinguish the LIFE-NAT network, it has the potential to provide fertile ground for strengthening the position of leading actors in network collaboration for nature-related initiatives. As Newig (2010) argued, actors can exploit network structural holes to act as brokers and connect otherwise disconnected groups and thus promote innovation and learning to address the complexity of the issues surrounding nature and ecosystem services. So, the lack of cohesiveness could be overcome if "bridging" actors demonstrate the ability and motivation to coordinate the activities of the sub-groups towards a common goal [32,55].

Further analysis could investigate (i) the trend of the density of networks for LIFE-NAT over time (ii) and the number of organizations participating to understand the further extension of the network and its consequences.

*Q2) What is the degree of homophily and heterophily of the LIFE-NAT network?*

According to the EI-Index, the LIFE-NAT network demonstrates homophily for the attribute "nationality".

We impute this result to the greater ease in which collaborative relationships between actors belonging to the same country are tightened, for example, thanks to the absence of the language barrier or the greater probability of belonging to networks already well established within the same territory. These conditions foster a greater sense of trust among organizations, which is also a condition needed to develop a learning-supporting environment, leading to a reduced perception of risk, both critical elements to understanding the dynamics of collaboration within a governance network [132,133,134].

Under LIFE-NAT, homophily for this attribute can cause a reduced exchange of resources (*e.g.,* new knowledge, information, innovative solutions outside national boundaries harming the resonance of the outcomes of nature conservation projects.

Based on the number of relationships concerning the attributes "level of governance" and "type of actor", the LIFE-NAT network shows a weak and moderate heterophily level, respectively. The research Hypothesis 2, therefore, is only partially verified.

It is relevant to highlight this evidence that the actors belonging to different typologies tend to collaborate in the same country. Therefore, LIFE-NAT proves to be a tool capable of breaking down the barriers to collaboration among different types of organizations, resulting in a more effective ML and NG in managing issues concerning nature.

Considering the number of EL and IL relationships again, it is observed a marked tendency of the majority of actors to collaborate with other ones belonging to different levels of governance, even if the overall level of heterophily for this attribute is low.

Thus, more incentives are needed to break down resistance to cross-level interactions. In particular, our analysis showed a limited involvement of the local authorities (*e.g.,* at the provincial and municipal levels). This cluster of actors play a critical role in nature conservation initiatives [135,136].

These stakeholders may include natural resource managers and planners, county or municipal governments, communities, local NGOs, natural resource-based industries, individual landowners, and locally-based interest groups [137].

Given the multiple institutional and geographic levels at which transboundary conservation decisions are made [138,139,140], opportunities for local stakeholders to participate in the decision-making process were not well identified yet [104,141].

Creating opportunities for local stakeholders to participate in nature conservation initiatives could mitigate gaps in communication among actors at multiple jurisdictional levels and, therefore, partly compensate for the low network density found within LIFE-NAT [136,141,142].

Meso-level organizations (*i.e*., the intermediates between different levels of governance and across resource and knowledge systems) can be critical players in this [138,141,143]. Our network analysis, applied to the LIFE-NAT priority area, reveals that these broker actors are NGOs and foundations, mainly at the national level, which can be facilitators in cross-level relationships. Within and among the other jurisdictional levels, they vertically integrate the decision-making process and, as meso-level actors, they serve a bridging role, enhancing bi-directional communication (*i.e*., among macro and local level actors) [137].

Looking at the macro-level (*i.e.,* the representatives who occupy positions of high-level, often administrative or regulatory authority), it is equally necessary to rethink the LIFE funding scheme, providing that local authorities must necessarily be included in the project partnership in the collaborative arrangements. The local authorities often intervene in the project scheme only as simple co-financiers. Instead, their participation should be strengthened and aimed at an operational role as Associated Beneficiaries (if not Coordinators) to be holders of the specific execution of some project actions. This would allow them to increase their level of responsibility for the protection, conservation and enhancement of local resources, providing for the presence of a supervisor who could facilitate the transfer of knowledge and skills where local authorities are lacking.

*Q3) What structural differences in MLG in the LIFE-NAT project networks are visible from 2014 to 2019? What differences are observable between different countries in Europe? What are the characteristics able to describe such differences?*

GEPHI® has proved to be an effective tool for effectively visualizing the complex interweaving of relationships consisting of nodes (organizations) and ties (relationships) (R3).

According to the core-periphery approach, the network might be structured in a core group of highly linked actors and a peripheral group of less connected organizations. Contrary to what one might believe, both network groups are equally relevant: the core part may include organizations acting as leaders and project catalysts, while the periphery may include organizations, such as network innovators or actors specialized in a particular taxon (*e.g.,* ornithological society) [144,145,146].

Although no core-periphery analysis was conducted, graphic representation has allowed us to highlight a core and a marginal area in the network's structure. Similar network structures have also been found in other cases documented in the scientific literature [71,129,147].

The analysis of the core of the graph allows identifying countries with the most significant number of LIFE projects funded, namely Italy, Spain, the United Kingdom, France, Bulgaria, and Germany. On the contrary, partnerships mainly constituted by organizations of the same nationality are observed at the network's edge.

Regarding the marginal area of the network, our results indicate a low tendency of neighbouring countries to collaborate on issues related to nature and biodiversity protection if compared with partnerships of the same nationality. Such evidence can predict some difficulties in establishing cross-boundary collaborations related to the conservation and restoration of ecosystems among neighbouring Member states. It is generally believed that cross-border cooperation for establishing ecological networks in Europe is not well developed: most plans are being developed only at the regional or sub-national level [148]. It seems that often cooperation is focused on large protected areas, such as national parks, but less on small Natura 2000 sites that may have a low recreational value [149]. One critical aspect of the Natura 2000 network is the connectivity in near-border areas where different national authorities have designated neighbouring sites using different methodologies [149,150].

The graphic representation of the core component of the network confirms the diffused presence of NGOs, transversal to several countries and widespread in the United Kingdom, Belgium, and the Czech Republic. This primacy of the United Kingdom over other countries is not surprising. British environmental associations, such as the Royal Society for the Protection of Birds, the National Trust and the Wildlife Trusts, claim millions

of members and a history dating back to the 19th century [151]. Moreover, in 2011 United Kingdom made the central document of its environmental policy 'The Natural Choice: ensuring the value of nature' White Paper, which focused, among other core themes, on the increased role of the third sector in strengthening human-nature connections [152]. In the United Kingdom, the objectives of the public and voluntary sectors are so close that NGOs contribute to the achievement of «official» environmental objectives [153,154].

The NGOs' role in the decision-making process in nature conservation interventions is well documented also in Czech Republic [155]. The Czech Society of Ornithology coordinated the process of implementing the Natura 2000 network. Moreover, some environmental NGOs developed a parallel priority list of sites with a high biodiversity value in the Czech Republic [156].

Focusing on Italy, the first country in the European ranking to present projects under LIFE-NAT from 2014 to 2019, a heterogeneous network emerged in which, among others, the research institutes, the parks and reserve authorities, and the universities stand out. These findings are consistent with Nita *et al*. (2016), where Italian partners have links with important organizations from other countries and can play a significant role in knowledge transfer and communication. Future analysis could be focused on understanding whether involvement in the core component of the network produces more successful collaborations in achieving results than partnerships on the fringes of the network [32,110].

The graphic elaboration returns a framework in which actors of the national level prevail. Researchers have divergent opinions about which jurisdictional level is the most influential [25,157]. The evidence found here may seem quite apparent if we consider that the protection and the conservation of nature and biodiversity issues are predominantly of national interest [158,159]. However, at the same time, the effectiveness of actions taken to address species and ecosystem degradation requires collaboration across governance levels [20,160] and, in particular, the involvement of local actors who are underrepresented in the analyzed network [161].

*Q4) To what extent state actors are widespread in the LIFE-NAT network as intermediary actors? Who are those able to catalyze the process of information, transmission, and control? What is their level of influence in the LIFE-NAT network?*

Our analysis of the centrality of organizations involved in LIFE-NAT projects shows NGOs' shared importance and influence with foundations and universities within the overall network. The centrality of NGOs is also confirmed by the absolute dominance of the ranking of the five organizations with the highest betweenness centrality index.

We can, therefore, say that Hypothesis 4 is not fully verified as our analysis has shown the fundamental role in initiatives for the nature of NGOs and not only of public actors, despite the latter having the mandate to manage natural resources. It follows that non-governmental actors are the most suitable to act as a bridge in the European network governance relations within LIFE-NAT.

This result is in line with the tendency of NGOs to emerge as political entrepreneurs due to their ability to bridge the network [32,127,162]. In this way, NGOs prove to have a concrete potential to act as gatekeepers among the other organizations and, due to the high values of betweenness centrality, they can exploit their position to control and benefit from the flow of resources from different parts of the network [100].

Results obtained here confirm the crucial role of NGOs and research institutes in coordinating and implementing LIFE-NAT projects; specifically, as Rozylowicz (2017) suggested, these two typologies of actors are mainly involved in the management of preparatory, monitoring and conservation activities [147]. Both these types of actors are to be considered fundamental for their commitment in the promotion of education, having as main objectives the dissemination of the information and environmental education. Sociedad Española de Ornitología (SEO) and Legambiente NGO hold the values of betweenness and degree centrality among the five highest central actors. These organizations have the highest number of partners and the potential to control the information flow within the LIFE-NAT network. So, they can act as network coordinators because they can enhance the capacity of the other actors to further access conservation funds [22,163].

Based on our results, it is possible to highlight how, within the LIFE-NAT network, the number of actors transmitting information between groups and, at the same time, having a high probability of receiving new information and knowledge is somewhat limited. The same results were reported for the LIFE sub-programme for the environment (LIFE-ENV) [129].

In particular, the low number of organizations having a positive value of betweenness centrality attests to a shallow intermediation capacity. This trend puts at risk the possibility of coordinating and associated beneficiaries to influence the entire structure of the network and the dynamics of future collaborations under LIFE-NAT interventions.

A more sustained approach of public authorities favouring private investors could ensure a higher flow of resources which could have multiplier effects and thus support the achievement of the European strategic objectives in nature conservation. Although LIFE Programme does not represent a source of long-term economic investment, it supports education as a key front for nature protection issues. Through the involvement of universities, research institutes and educational centers, LIFE supports education in promoting conservation measures and disseminating new approaches and best practices through specific Project Actions [62]. Just to mention an example, the LIFE-Brenta 2030 project (https://www.parcofiumebrenta.it/en/life-brenta-2030/), within the Project Actions for Communication, involves local schools to promote environmental education on nature and biodiversity issues. In addition, among the Preparatory Project Actions, it provides training courses aimed at stakeholders in the project area, for the improvement of the management of Natura 2000 sites in the same area.

Central actors are diffused in countries of the Mediterranean basin (*i.e*., Italy, Spain, and Greece), generally endowed with limited funds for addressing the multiple threats that undermine the nature protection and integrity of Mediterranean ecosystems [164]. A higher number of funded projects in the countries of Southern Europe, such as Italy and Spain, is due to more robust project design and management capabilities [110]. Moreover, the high involvement is motivated by the richness of species and habitats they host, which require a high standard of protection against human pressure (*e.g.,* the Mediterranean basin has 35 biodiversity hotspots; in the Balkan area, Bulgaria hosts up to 1300 endemic species) [165,166].

Southern European countries are crucial actors in implementing initiatives in favour of nature and ensuring the results in terms of collective actions within the LIFE-NAT. In contrast, countries that recently joined the EU are less represented within the network. This evidence confirms the findings of previous studies on nature conservation projects, such as the one of Nita *et al*. (2016) [110].

Within LIFE, Sociedad Española de Ornitología (SEO) and Legambiente NGO are the organizations with the highest betweenness centrality. Due to their influence and control on information transmission at the national jurisdictional level, they are fundamental communicators and facilitators in disseminating resources and new knowledge among actors on different levels. Given these characteristics, they can also be effective interlocutors with public authorities, having a role in the decision-making process and positively shaping the power relations within the policy arena [54].

However, if actors do not share their knowledge across national borders, the risk of declining interest in collaborative governance initiatives in nature conservation could emerge. On the contrary, transnational cooperation may improve project outcomes by making their impact sustainable [110,167].

*Q5) To what extent does the LIFE-NAT priority area facilitate the emergence of non-governmental actors as new policy entrepreneurs?*

Based on R5, it can be said that the activation of LIFE-NAT projects across the 28 EU Member States (now 27) confirms the multi-participatory approach supported by LIFE for the achievement of the objectives set out by the European plans and strategies for nature and ecosystems.

A multi-participative approach provides many options for decision-makers in contrast to blueprint solutions or panaceas [168,169]. Collaborative governance emphasizes a variety of entities (individuals, organizations, and institutions) connecting across levels to broaden intervention options in managing the social-ecological system [143,170] by providing practical solutions through processes of learning, coordination and cooperation [18,133].

The direction toward a multi-participatory approach has also been observed for Natura 2000 Network governance, reflecting the broader trends toward multi-stakeholders' participation in EU environmental policy and governance. In particular, the analysis conducted by Ferranti *et al*. (2013) shows how a rigorous scientific approach in the first years of Natura 2000 has empowered scientific experts from research institutes, European institutions and environmental NGOs [52].

Environmental NGOs play several roles in the complex political landscape where decisions about biodiversity conservation are made. They have supported national governments and the private sector in setting aside millions of hectares worldwide in terrestrial and marine protected areas [*e.g.,* 171]. They have conducted

some of the most successful projects on species and ecosystem restoration [*e.g.,* 172], establishing overtime as primary transformative political agents working alongside other social groups to protect the global commons [173].

Our results from the analysis of the network within LIFE-NAT confirm the strong presence of NGOs as LIFE-NAT project beneficiaries, particularly in the leading role of coordinating beneficiaries.

This evidence for the LIFE-NAT network might have its roots in the prominent role these actors have acquired since the early 1990s in biogeographic seminars, which are large-scale political events aimed at presenting lists of sites to be protected [174]. Thanks to their scientific contribution to identifying sites to be protected, the NGOs have distinguished themselves in the European debate [175]. As a result, during the seminars, the European Commission and environmental NGOs worked together to achieve common objectives: the effective and efficient implementation of Natura 2000 and the halting of biodiversity loss in the EU [176].

Concerning what was formulated with our research Hypothesis 5, bottom-up collaborative governance in which the decision-making process is determined not only by State actors has been verified.

Nevertheless, some authors point out that nature conservation projects carried out by small environmental NGOs are generally limited in time, space and resources and, in particular, underline the difficulties of documenting their experiences and spreading out the lessons learned [173,176]. As a result, many of these shreds of evidence and good practices are not scaled up and incorporated into national policies [173]. As the main programme for funding nature projects, LIFE represents an opportunity to overcome these limits by supporting environmental governance and facilitating the participation of small partnerships to determine more relevant impacts.

In recent years, NGOs became active policy entrepreneurs, defined by Roberts and King [177] (p. 147) as "those that, working from outside the formal government, introduce, translate, and help implement new ideas into public practice". They collaborate with governments at the national and international level (public-NGO alliances) and private organizations (private-NGO alliances). Given the trend to decentralize nature conservation policies and its budget, more collaboration between environmental NGOs with businesses and municipalities becomes necessary to realize nature projects [178].

A typical LIFE-NAT project consists of concrete conservation actions, such as biodiversity inventories, monitoring, educational and dissemination activities and project management. As a result, a project partner can be selected for its technical expertise (*e.g.,* forest management), political connections and influence at the national level, knowledge of the project area, capacity to manage funds or provide co-financing [31,179].

In order to involve the right associated partner, the project coordinator needs to foster a mutual exchange of resources [180]. For example, the cooperation could start with an exchange of skills: businesses could gain access to knowledge about the topics related to their core activities. At the same time, NGOs may be interested in specific resources and competencies of the business. The LIFE Programme promotes this kind of horizontal cooperation to ensure the success and the impact in the long term of strategic initiatives for nature protection.

Considering the total number of beneficiaries constituting the LIFE-NAT network, actors of national and regional levels predominate; this is not surprising if we consider the strong presence in European countries of a prevalent national and regional approaches in biodiversity management and conservation.

Rozylowicz *et al.* (2017) published a network analysis of Romanian LIFE-NAT projects where the NGOs' technical expertise and policy influence at the national level emerged [147]. This feature tends to be the case in other geographical contexts, such as the USA: in his analysis Schoon (2017) evidenced the dominance of national NGOs by describing the dynamics over time of environmental governance network in the Arizona borderlands. In that case study, NGO-led initiatives greatly changed the collaborations from previously government-driven projects to bottom-up types, maintaining the ties built before [134]. Even if, in most Member states, local actors are institutionally involved in concrete actions to protect nature and biodiversity (*e.g.,* management of Natura 2000 sites), in our analysis, a low degree of involvement of actors at the municipal level emerges. In our opinion, the absence of such actors could be justified mainly by a general lack of skills (*e.g.,* project design competencies and English proficiency), which drastically reduces their presence as beneficiary actors in LIFE projects [110].

Although ensuring biodiversity conservation is a primary function of public bodies [181], it is expected that several countries will not be able to achieve the goals without support from other societal actors, such as NGOs [173]. Thus, this calls for hybrid forms of environmental governance among states, markets and

communities [54]. In this context, the LIFE Programme constitutes a fertile scenario to construct and develop cross-sector alliances to address the national funding gap for nature and biodiversity protection [62].

Park and reserve authorities make up the type of beneficiaries most represented in the LIFE-NAT network after NGOs.

This result proves that the category of park and reserve authorities plays a strategic role to be taken into account for the implementation of actions related to nature and biodiversity supported by LIFE-NAT, especially in the regions of Europe where there is little access to funds for nature (*e.g.,* Italy), in which they play roles of greater centrality in the network of the different partnerships.

Therefore, park reserve-authorities can play a crucial role in ensuring a MLG approach involving multiple agencies, NGOs, and communities across municipal, provincial, regional, national and international levels to achieve the conservation outcomes pursued by the LIFE Programme [182,183].

*Limits and future perspectives*

For this study, the SNA has constituted the central approach, configuring as an effective tool for studying non-governmental and intermediary actors in the LIFE-NAT intervention sector.

Nonetheless, concerning the possible replication of the methodological approach adopted, some caveats and limitations should also be taken into account, particularly in finding information for the creation of the database. First of all, it is not easy to find some information, even substantial, relating to the projects (*e.g.,* the reference website) and the beneficiary actors, such as the organization's unique name, which is essential for classifying the type of actor. Secondly, it should be noted that the results of the analysis conducted for the characterization of the actors are to be considered partial, as the co-financiers have not been considered since they are actors involved in the project only for their financial contribution. The extension of the analysis to these actors, together with information on the economic resources allocated to each co-funding beneficiary (to date, they are not made transparent), would allow the categorization of the actors also from a financial point of view. Despite these difficulties and limitations, the results obtained through this analysis have highlighted some critical aspects in the study of environmental and network governance approaches that can give rise to ideas for the formulation of further hypotheses to develop new evidence in these research fields.

**Conclusions**

Considering the nature conservation projects set up under LIFE-NAT from 2014 to 2019, the study depicts how multiple actors address shared problems related to nature and biodiversity through ML, and NG approaches from different geographical and jurisdictional levels. Specifically, SNA, as the research methodology of this study, revealed the intermediary organizations and their structural characteristics within the network of partnerships.

The LIFE-NAT priority area represents a concrete example of how a multi-participatory and collaborative governance approach can be implemented to manage issues concerning the protection and conservation of nature. In this context, public actors can benefit from the intervention of non-state actors for innovative and effective solutions. The NGOs and the foundations collaborate both nationally and internationally, contributing with their technical expertise and political influence to implementing conservation projects and concrete measures for the protection of nature.

The marked tendency to establish relationships between actors of the same nationality emerged as one of the limits to collaborative governance, potentially undermining the achievement of sustainable impacts in the long term and, therefore, the achievement of biodiversity objectives by 2050. In this regard, the European Commission should stimulate cooperation between partners across borders. Therefore, it is possible to close the collaboration gap between North-South and Eastern European countries.

In this regard, the network measures calculated through the SNA can be constituted as essential indicators of the influence and importance of the actors in the network, able to identify the intermediary organizations in the LIFE-NAT network and the other priority areas of the LIFE Programme. By supporting these organizations (*i.e.,* NGOs and the foundations) with a crucial role in collaborative and network governance, a more widespread flow of information and dissemination of knowledge and innovative solutions would be ensured.

Biodiversity conservation goals pursued with low stakeholder participation at the provincial and municipal levels may remain unfulfilled due to a lack of joint efforts and local investment. Cross-sector alliances with these actors are, therefore, an essential element in the framework of collaborative environmental

governance. Based on our results for the LIFE-NAT network, more investment should promote this type of multi-level cooperation.

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