



Unravelling non-human agency in sustainability transitions

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ABSTRACT

While agency has received considerable attention in recent sustainability transitions studies, as well as in the literature on socio-ecological systems and sustainability transformations, the focus has been on the agency of humans. Given the emphasis on infrastructures and material culture in sustainability transitions studies, it is surprising that non-human agency has not received more attention. This paper aims to add to the body of work on agency and actor-oriented approaches in sustainability transitions, and addresses this gap by investigating the role of non-human agency in shaping sustainability transitions. Through an application of Actor-Network Theory, we followed the *Bagrada hilaris* pest, and analyzed the roles performed by the *Bagrada* as a so-called actant within a network of humans, as part of a transition-in-the-making towards more sustainable food systems. The *Bagrada* has been a key actant in provoking changes towards sustainable pest management in Chile, destabilizing regime practices associated with pesticides, and creating and mediating relationships between different human actors. In terms of transition theories, particularly the multi-level perspective, this case illustrates the relational nature of agency. The main theoretical implications are that: a) actants from all levels (niche, regime, landscape) are linked in networks of relations that make change happen; b) the landscape level is not void of agency; c) boundaries between levels are fluid. We conclude that relating to non-human actants and understanding how to mobilize them for normative goals can help catalyze sustainability transitions.

1. Introduction

The issue of agency has been gaining prominence in sustainability transitions studies (de Haan and Rotmans, 2018; Wittmayer et al., 2017), as well as in the neighbouring field of sustainability transformations (Westley et al., 2011, 2013). Sustainability transitions studies were initially criticized for an over-functionalistic approach and for neglecting issues of agency and power struggles (Duygan et al., 2019; Fischer and Newig, 2016; Grin et al., 2011; Shove and Walker, 2010; Smith et al., 2005). This critique led to new theorizing around agency in transitions, furthering our understanding about the actions, strategies, functions and roles different actors perform in a process of transition. Recent studies have contributed to understanding transition politics by conceptualizing (shifting) power relations between actors in sustainability transitions (Avelino and Wittmayer, 2016), and has theorized the roles of different actors in transformative change (Wittmayer et al., 2017; de Haan and Rotmans, 2018). Empirical studies have shown how diverse actor groups can contribute to transitions; including: social movements (Ornetzeder and Rohrer, 2013; Seyfang et al., 2014);

incumbents (Späth et al., 2016; Musiolik et al., 2012; Turnheim and Geels, 2013), technology manufacturers (Budde et al., 2012; Musiolik and Markard, 2011); policy makers (Quitau et al., 2012), and intermediary actors (Hargreaves et al., 2013; Kivimaa, 2014).

Understandings of agency in sustainability transitions have been based on concepts such as (collective) institutional entrepreneurship (Duygan et al., 2019; Hassink et al., 2018; Heiskanen et al., 2019; Hermans et al., 2013; Jolly et al., 2016), and institutional work (Fuenfschilling and Truffer, 2016; Rogers et al., 2015). Concepts such as institutional entrepreneurship and institutional work refer to different activities through which actors may be able to create new institutions, as well as disrupt or maintain existing dominant ones (Duygan et al., 2019; Fuenfschilling and Truffer, 2016; Rogers et al., 2015). These actions include the construction of expectations and visions (Berkhout, 2006; Bakker et al., 2012; de Haan and Rotmans, 2018; Klerkx and Aarts, 2013; Westley et al., 2013); the creation of alliances and networking (Musiolik et al., 2012; Kivimaa et al., 2019a; Westley et al., 2013); the creation of legitimacy and institutional support (Kivimaa et al., 2019a). Other studies have indicated the role of intermediary actors as relevant

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agents that catalyze transitions due to their mediating function among dispersed, diverse or previously disconnected actors, for instance, by connecting, coordinating or helping to distribute relevant information for transitions (Bush et al., 2017; Fischer and Newig, 2016; Kivimaa et al., 2019a). A few studies have proposed more comprehensive theories on transformative agency (Westley et al., 2013), and recognized different agency roles actors should perform for a transition to happen (de Haan and Rotmans, 2018). Lawrence et al. (2013) have argued that agency is a task distributed across several actors. This is aligned with studies with an institutional work perspective, that emphasize the role of collective actors in transition, explicitly refraining from heroic formulations of sole actors, as often depicted in the institutional entrepreneurship literature (Jolly and Raven, 2015; Smink et al., 2015).

While many studies have improved both our empirical and theoretical understanding of agency in sustainability transitions, they have been limited to human agency. In this paper we pay attention to the role non-human actor play in facilitating change towards more sustainable systems. More specifically, we consider the role of non-human agency in relation to human agency in a case of sustainable food systems transition, by analyzing a so-called ‘transition-in-the-making’ (Elzen et al., 2011). We show that taking non-human agency seriously can help better understand processes of transition across multiple levels that may impact the long-term trajectory and significance of a sustainability transition. While non-human actors, such as pests, diseases or viruses, can be considered a material foundation influencing social change within an MLP framework, ‘real agency’ is most often attributed to human actors. Correspondingly, we ask the following research question:

What is the role of the non-human actor *Bagrada hilaris* in shaping the transition-in-the-making towards more sustainable food systems in Chile?

We answer this question by following the relations set in motion through the arrival to Chile’s central area of an agricultural pest *Bagrada hilaris*, or *Chinche Africano*¹ (painted bug). Since its appearance, the *Bagrada* has been destabilizing the local pest management regime –based on high use of chemical pesticides– while prompting changes in the practices of conventional farmers towards integrated pest management (IPM). In Chile, the excessive use of pesticides and resulting residues in vegetables has been recognized as a problem by public agencies, particularly with regards to the domestic vegetable market (Muñoz-Quezada et al., 2016). By taking the example of the *Bagrada* and its relations to other actors, (human and non-human), we uncover and analyze the actions and roles a non-human actor can play in a process of transition-in-the-making towards more sustainable food systems.

In doing so, we contribute to work on sustainability transitions, and multi-level perspectives in particular, by exploring the agency of a non-human actor from the landscape level, the *Bagrada* pest, in provoking and catalyzing sustainability transitions; particularly, in the Chilean agricultural sector. We also further contribute to studies addressing sustainability transitions in the agricultural sectors or the agri-food system (Bui et al., 2016; Ingram, 2018; Loconto et al., 2017; Schiller et al., 2020), and the need to take into account (biological) material relations in sustainability transitions processes and analysis (Birch, 2016; Coenen et al., 2012; Grin et al., 2011; Markard et al., 2012; Rosin et al., 2017; Svensson and Nikoleris, 2018; Kok et al., 2021). This has also been noted as particularly relevant for food system transitions (Darnhofer, 2020; Klerks and Begemann, 2020; Ollivier et al., 2018; Pigford et al., 2018).

In what follows (Section 2), we further develop our theoretical framework for analyzing the role of non-human agency in sustainability.

In order to do so, we make a complementary use of two theories: the Multi-level Perspective (MLP), a theory that conceptualizes transitions and that provides an heuristic structure for guiding the search for patterns, causes and impacts of different phenomena during transition (Ingram, 2015); and, Actor-Network Theory (ANT) which allows us to account for non-human agency (Shim and Shin, 2019; Shin, 2016). ANT has been referenced by transition scholars as a useful theory for examining processes of transition-in-the-making (Geels, 2010). We then provide the case description and methods. This is followed by a presentation of our findings about the agency of the *Bagrada* in terms of its actions, the networks it creates or induces, as well its relational role within these networks. Finally, we discuss our findings in connection to the literature on non-human agency and sustainability transitions and provide our conclusions.

2. Theoretical framework

2.1. Transitions in-the-making

Transitions are processes of technological and social change that is radical or considerable, so that the way a socio-technical system (the regime) functions is profoundly transformed (Markard et al., 2012). We refer to a transition-in-the-making as a process that we cannot be certain will progress to an overall transition (e.g., the complete elimination of chemical pesticides in the Chilean vegetable food system), but in which we can see the emergence of (new) practices, networks and framings that question and destabilize an existing regime, having the potential to start and lead to a broader transition (Elzen et al., 2011). We are thus interested in emergent practices, networks and framings that are able to disrupt and challenge institutions (formal and informal), technologies, organizational, and political and/or cultural dimensions configuring a pest management regime based on the heavy dependence on chemical pesticides. Furthermore, a transition-in-the-making examines on-going processes of transition during a limited period of time; focusing on occurring developments, practices, actions, projects (Loconto et al., 2017). Whether or not these efforts will lead to a transition (e.g. a regime change affecting a broader spatial scale) can only be determined retrospectively, which is out the scope of this study (Diaz et al., 2013).

2.2. Analytical lens: unravelling non-human agency in transitions-in-the-making by connecting the multi-level perspective and actor-network theories

Building upon Diaz et al. (2013), we propose a cross-over and complementary application of the Multi-level Perspective on socio-technical transitions theory (MLP) and Actor-Network Theory (ANT) to examine the agency of the *Bagrada* in the transition-in-the-making from heavy pesticide use towards more sustainable modes of production. While the MLP can be a useful heuristic to position different actors involved in a transition at different levels (Diaz et al., 2013), the theory does not provide the analytical lens to analyze actor (inter)actions (de Haan and Rotmans, 2018; Diaz et al., 2013; Elzen et al., 2012; Ingram, 2015). Diaz et al. (2013) brought MLP and ANT together to analyze interactions between niche and regime actors, and it was also suggested by Pigford et al. (2018) as a way to better account for materiality and ecology in sustainability transitions. Here, we make use of ANT in order to unravel the actions of the *Bagrada* non-human actor. In what follows, we explain both theories and how we complement them.

2.2.1. The multi-level perspective and agency at different levels

The multi-level perspective on socio-technical transitions (MLP²)

¹ *Bagrada hilaris* corresponds to the bug’s scientific name, and *Chinche Africano* to its common name used by people in Chile. In this paper we will use both names. We will make use of the common name *Chinche* in interviewees quotes, as was the name more often used by them, or when we provide a descriptive account of the pest. Whereas, we will use the scientific name *Bagrada* when referring to the bug as an actant with its own agency.

² There are also other multi-level perspectives on socio-technical transitions, e.g. the one proposed by Shin & Park (2017) which provides a multi-level analysis of users, society, and ecology, but here we follow the model introduced by Geels (2004).

depicts transitions as emerging from the interplay of three analytical levels: landscape, socio-technical regime, and niches. According to different interactions among these three levels, different transition pathways are developed, for instance, transforming or replacing an existing socio-technical regime (Geels and Schot, 2007).

The socio-technical regime refers to social (e.g. organizational, institutional, political, cultural, market) and technological arrangements configuring and stabilizing, in this case, the dominant Chilean local vegetable-food system (Ingram, 2015). The regime is usually locked-in to incremental innovation pathways that hinder transformation (Brunori et al., 2013; Seyfang et al., 2010). The niche level represents a source and breeding ground for radical innovations that may start a transition process with the potential to transform the regime (Geels and Schot, 2007).

In a conventional MLP model, significant transitions are more likely to begin at the niche level and aggregate up to the regime and landscape level through a somewhat linear process. By assuming niche development as the starting point of transitions, this model did not take into account other transition pathways (Geels et al., 2016) wherein change originates from landscape or regime level (Kivimaa et al., 2019a). Some authors have highlighted the critical role of 'hybrid actors' (actors belonging to both the niche and regime) play in advancing sustainability transitions, as well as the role of 'intermediaries' and 'boundary spanners' for mediating and connecting other actors from different MLP (or other) levels (Kivimaa et al., 2019a, 2019b; Smink et al., 2015). As such, changes have been proposed which emphasize a less linear change trajectory, and a broader diversity of potential actors.

The landscape corresponds to macro-level factors, while also being a context of social and physical factors where niches and regimes are situated (Smith et al., 2010). Because the landscape level highlights the 'technical and material backdrop that sustains society', it is the level that most explicitly addresses materiality (Geels, 2011; Svensson and Nikoleris, 2018). Landscape level inducements are fundamental in the development of all transition pathways, putting pressure to the regime and opening opportunities for niches (Geels et al., 2016; Geels and Schot, 2007). The general assumption is that actors can only respond to this level, and that there is no room for agency (Raven et al., 2012) or at least actors cannot influence it in the short run (Geels and Schot, 2007). Thus, there is a tendency to include it as a 'background': a scale with no 'activities' (Coenen et al., 2012). In a systematic literature review, Fischer & Newig (2016) identified actors at the landscape level as having weak or no agency, although studies have suggested that civil society could be a landscape actor insofar as civil society represents general landscape-level cultural trends able to induce regime changes (Seyfang et al., 2010). In this article we elucidate the agency role of a landscape-level actor, the Bagraña pest, in provoking sustainability transition in the Chilean agricultural sector. It has been argued earlier that in transition studies the role of biological and ecological agents, such as pests, needs to be contemplated better (Pigford et al., 2018; Vermunt et al., 2020). However, we must first clarify how we conceptualize a pest as an actor.

2.2.2. Actor network theory (ANT)

ANT was proposed as an alternate approach to social theory by science and technology study scholars Michel Callon and Bruno Latour (1981). ANT can be usefully applied to analyses of technology in research that move beyond the assumption that technology is simply an instrument utilized by humans (Shim and Shin, 2019; Shin, 2016). Instead, ANT claims that any element of the material and social world can be an actor, or in their parlance, an actant. Hereinafter, we distinguish both human and non-human actants, and when only 'actor' is used it refers to human actants. Following the logic of ANT, any action is the product of a network of actants who have characteristics and capacities that work collaboratively in a sphere of action. As such, a change agent (or mediator in ANT terms) is any 'entity' – whether this is 'social', 'natural' or 'technical' – that problematizes or destabilizes a network, or

enables others to come together by connecting, mediating among and mobilizing others (Latour, 2005; Sayes, 2014); contributing to previously unrealized action (Legun and Henry, 2017; Rosin et al., 2017). The challenge of applying ANT is that it can be counter-intuitive in so far as it 'reverses our common understanding of actors and agency, e.g., when it cuts across the subject-object division underlying our thinking about the world we live in' (Jessen and Jessen, 2014).

To be clear, ANT does not attribute intentionality to non-humans neither does it presuppose that agency implies intentionality (Sayes, 2014). Intentional human action is a type of action that it is not the only nor incompatible with other forms of agency, and indeed, must rely on external agencies beyond individual control (Sayes, 2014).

Following ANT, humans and non-humans are linked together in a web of relations referred to as actor-networks (Iskandarova, 2016). Networks (loosely defined) do not naturally and inherently exist. Networks emerge when multiple actants start interacting with each other, and form relations. Networks are constituted and re-constituted in actual processes of doing (Arora and Glover, 2017). The stability and cohesiveness of a network is a product of the ability of any actant to become indispensable to the continuity of the network, enrolling the other participants (Rosin et al., 2017).

In ANT, the process by which actants make relations is referred as translation. Translation involves four phases:

- i Problematicization (actants frame problems and solutions, identifying potential allies to be enrolled in their network);
- ii Interessement (the actions actants employ to interest others to enroll them in the network);
- iii Enrolment (a successful interessement leads to setting-up the alliances with the interested actants, while negotiating and coordinating their roles and interest within the network);
- iv Mobilizing allies (identifying spoke-persons that legitimately represent the network in order to gain support from others and expand the network).

Translation is not a linear process but supposes continuous moves and countermoves among the different phases according to on-going (re) negotiations and (re)making of relations between actants. For instance, actors may (re)negotiate problem framings and their solutions, and relations between actants can be collaborative or conflictual. Relations can also be primarily semiotic or material in ways that become mutually constitutive in a network. That is, a material is understood conceptually within a network (e.g. the Bagraña is conceptually a pest that eats vegetables within an agricultural network) and a concept is only meaningful insofar as it is materially grounded in a network (the meaning of pest management is dependent on the material presence of plants and bugs, and may not have the same meaning, or any meaning at all, in another set of material relations) (see Law, 2009). This semiotic-material stance of ANT helps to account for both the material characteristics and symbolic meanings that enable non-humans to act in ways that are coherent to us, and it describes how networks are stabilized.

2.2.3. Connecting the MLP and ANT to unravel non-human agency

Some scholars have pointed-out that it is unclear how relational ontologies –including ANT– can be useful to analyze transition dynamics beyond the empirical mapping of cases (Geels, 2010), and to the incompatibility between MLP levels and ANT's flat ontology, which denies the analytical usefulness of 'levels' (Geels, 2011). ANT is not an explanatory theory. It does not seek to explain why or how a network takes a certain form (Latour, 2005). Instead, Latour presents ANT as a method of how to examine and describe relations and actions. In applying ANT, the focus should not be in mapping the resultant network, but on how the network forms; thus, on the work that actants do to create and sustain those networks and relationships (Müller and Schurr, 2016). Whereas, studies crossing-over MLP and ANT have contributed to

unravel how the boundaries of the niche are fluid (Diaz et al., 2013).

We also want to note that the phases of translation resemble many actions recognized by previous studies on agency and transitions that have not used ANT. For instance, problematization relates to actions such as vision making, or the framing of problems and solutions (Bakker et al., 2012; de Haan and Rotmans, 2018; Klerkx and Aarts, 2013; Westley et al., 2013). Actions such as the creation of alliances (Musiolik et al., 2012; Kivimaa et al., 2019a; Westley et al., 2013), connecting actors and facilitating negotiation amongst them (Smink et al., 2015; Kivimaa et al., 2019a), are similar to translation phases of interessement, enrolment and mobilizing allies. Likewise, the mobilizing of allies relates to what previous transitions studies have identified as the creation of legitimacy and institutional support (Kivimaa et al., 2019a). Hence, ANT remains coherent with the actions attributed to actors by previous works examining (human) agency in sustainability transitions.

The MLP will serve as heuristic to conceptualize the transition from heavy use of pesticides (regime) towards integrated pest management and biological control, and to position the different actants involved in this transition-in-the-making. ANT will allow us to follow the *Bagrada*, tracing the emergent networks of relations that surround it. Through further analysis of these networks, and by focusing on the actions and relations of each actant, we can better understand the roles the *Bagrada* and other actants are playing within their networks, as well as the relevance of these roles and relations for transitions.

3. Case description and methods

3.1. Case description

This study is a qualitative study based on an empirical case study of the *Bagrada hilaris*, a bug that has been recorded as an aggressive pest for several vegetables in Asia, Africa, Europe, North America and, recently, in South America (Faundez et al., 2016, 2017). In Chile, the *Bagrada* was first detected in late 2016 in Estero Las Cruces, Metropolitan Region (Faundez et al., 2016), very close to the case study area (Lampa), from where it spread to other Chilean regions (Faundez et al., 2018). It is suspected that the pest arrived by land or international air transport (Faundez et al., 2016).

As will be elaborated in the Findings Section, since its arrival, the *Bagrada* has been destabilizing the existing pest management regime at the local, regional, and to a lesser extent Chilean national levels. This pest management regime is based on the high use of chemical pesticides (Zolezzi, 2012; Muñoz-Quezada et al., 2016); and external inputs in general. The problem of high-pesticides use in Chile has been made public by researchers (Elgueta et al., 2017; Muñoz-Quezada et al., 2012, 2016), by newspapers (Cornejo, 2019), and to a lesser extent by the Ministry of Agriculture, through the agency INIA (Zolezzi, 2012). Particularly, in the Metropolitan Region during the periods 2003–2007 it was found that 61% of lettuces could not be exported to the European Union due to pesticides residues, only 28% of spinaches complied with Chilean maximum pesticides allowed (lower than the EU), and 92% of cabbages presented *methamidophos*, an extremely dangerous pesticides for human health that was not allowed by the Ministry of Health (Rojas-Walker et al., 2007).

The *Bagrada* has also been mobilizing a whole network of actants –human and non-human– working to get the pest under control. Given the challenges associated with high-pesticides use, these networks have had to search for alternative methods such as Integrated Pest Management (IPM), and biological control. IPM has been defined as ‘...a decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates) in an ecologically and economically sound manner.’ For a farmer, IPM implies the following: i) simultaneous management of multiple pests; ii) regular monitoring of pests, and their natural enemies, and antagonists as well; iii) use of economic or treatment thresholds when applying pesticides; and iv) integrated use of multiple, suppressive

tactics (Ehler, 2006).

While through IPM a reduction in farmers’ pesticide use and dependence might be achieved, it is not a radical innovation targeting, for instance, radical changes in farmers’ practices (e.g. eliminate chemical use), or other political and institutional dimensions. Lamine (2011) indicates how IPM might seem less radical when compared to, for example, organic agriculture, as IPM entails a reduction in the use of chemicals, whereas organic farmers must dispense from their use. Still, IPM remains relevant because it forms part of several conventional farmers transition trajectories towards ecological practices; including organic agriculture (Lamine, 2011). We accept that a transition to more responsible pesticide use is a small intervention in the broad scheme of agricultural systems, and so it may easily be envisioned as simply a process of spraying quantifiably less. However, moving away from broad-spectrum chemicals routinely applied, to targeted chemicals applied strategically and in combination with other pest-management strategies requires a shift in basic, long-practiced cultural norms in farming. Previous food systems transition studies have addressed IPM as a niche (Lamine, 2011; Loconto et al., 2017), that might help a transitions towards more sustainable agricultural practices, and more general ‘ecologization’ of agricultural practices (Lamine, 2011). Hence, such a transition process and efforts should not be underplayed as a breeding ground for transitions due to a supposed lack of radicality.

The transition-in-the-making process undertaken by the *Bagrada* and its related network can be linked to what Smith et al. (2005) coined as an ‘endogenous renewal context’. Such a context arises as a response from the regime to external pressures for change –in this study, caused by the *Bagrada* aggressively eating crops–, and are characterized by a conscious and articulated response from regime members willing to change the regime. However, because innovative activity is constructed from within the regime itself, innovations tend to be incremental and path-dependent (Smith et al., 2005).

The *Bagrada* case illustrates an on-going process of a network of actants emerging around a technological niche (in this case, IPM and biological pest control overlapping niches) in their attempts to bring-up changes within the current Chilean domestic vegetable production regime; specifically, to significantly reduce farmers’ heavy use and dependence on chemical pesticides for vegetable production. For this, we consider the case of the *Bagrada* as a good example of a transition-in-the making process.

3.2. Methods

Qualitative data was gathered between September 2018 and June 2019 in Chile, following similar methods from studies examining non-human agency through ANT (Shim and Shin, 2019; Shin, 2016), or complementing ANT with MLP (Diaz et al., 2013). In order to follow the *Bagrada*, the lead author undertook observation from November 2018 until July 2019 in different activities related to the *Bagrada*; these include the *Mesa-multisectoral de Bagrada hilaris de Lampa* (Multi-sector round-table for *Bagrada hilaris* from Lampa), and in public agencies organized seminars related to the *Bagrada hilaris*. In addition, semi-structured interviews with some Mesa participants were conducted, and secondary data was revised (Table 1.).

The Mesa is a public-private platform where once a month different actors meet in Lampa, a rural county of the greater Metropolitan Region, to discuss how to manage the *Bagrada* pest. Among the Mesa participants are affected farmers, and public officers from various municipal, metropolitan, and regional departments. INIA, a private-public agency aimed at developing agricultural research and extension, and the SAG (*Servicio Agrícola y Ganadero*; National Agricultural and Livestock Service), the national agency responsible for the country’s phytosanitary control and protection, are also engaged. Both agencies are funded by the Ministry of Agriculture. The lead author also attended and undertook observation in two seminars related to *Bagrada hilaris*: i) Expo-Chile-Agrícola (October 2018, Santiago), where the SAG presented the

Table 1
Data gathering methods.

Type of data gathering	
Semi-structured interviews	6 interviews with participants from the <i>Mesa-multisectoral de Bagrađa hilaris de Lampa</i> : 2 Farmers affected by the Bagrađa 1 Public Officer from the Municipality of Lampa 1 SAG Officer 2 INIA Officers
Observation of actors interactions	At 6 meetings of the <i>Mesa-multisectoral de Bagrađa hilaris de Lampa</i> At two seminars organized by public agencies (SAG and INIA, respectively) where governmental agencies plans and measures to tackle the Bagrađa were communicated to the broader public, mainly farmers
Document analysis	News related to the Bagrađa from different webpages (24 horas, 2017; Bierwirth, 2018; Ibañez, 2018; INIA, 2020; SAG, 2019) Official resolution on the SAG's plan to tackle the Bagrađa (SAG, 2017)

actions it has taken in relation to the Bagrađa; and, ii) a seminar where the project 'Developing an Integrated Pest Management with low environmental impact for mitigating *Bagrađa hilaris*' populations for a competitive and sustainable horticulture' was launched by the INIA (November 2018, Lampa, Metropolitan Region). The seminar included presentations by INIA researchers and SAG officers.

Observations in the Mesa and in seminars were complemented with six purposive semi-structured interviews conducted with some participants from the Mesa. Interviews were carried out with two affected farmers, an officer from the SAG, two INIA regional extension officers, and a Municipal agricultural officer. Interviewees were asked about how they have been affected by the Bagrađa, and what they envision as solutions. They were also asked about what they expect from, and contribute to the Bagrađa network that exists around the Mesa. A personal history focusing on what has happened since the Bagrađa became a significant pest was also recorded for each interviewee. Finally, secondary data was reviewed. This included different public agency documents related to the Bagrađa (SAG, 2017), as well as webpages news (Table 1).

Data was coded and analyzed using Atlas.ti software. A combination of deductive and inductive-coding was applied. Deductive codes were derived from the application of MLP and ANT theories, such as MLP levels of actants involved; actions taken by different actants (e.g. enrolment, mobilizing allies, others); relations between actants, while at the same time being open to emergent observations (e.g. interactions of conflict, collaboration; resources).

4. Findings

In this section we first reconstruct the actor-network that has been invoked by the Bagrađa, tracking the relations between different actants (from different MLP levels) that have been enrolled into the Bagrađa's network. Thereafter, we explain the roles the Bagrađa plays within this network, analyzing how, by enrolling other actants into its network, it has provoked changes in their roles and relations. Finally, we summarize our findings

4.1. Networks invoked by the Bagrađa: tracking the relations

Around September 2016 the Bagrađa, also known as the Chinche, arrived for the first time to the central area of Chile (Metropolitan Region), affecting different counties including the Municipality of Lampa. The Bagrađa spread rapidly (also to the Valparaíso Region) (Faundez et al., 2018), eating considerable hectares of vegetable crops, resulting in severe losses to farmers (Farmer 1, Farmer 2). As a farmer indicated, 'we were desperate' (Farmer 1). Since its arrival, the Bagrađa has

problematized the issue of 'pest management', enrolling a whole range of different actants from the regime into its network, while also triggering the formation of two new regime actors networks; these networks are: i) the Lampa's Farmers Association, and ii) the Mesa (described above) (Farmer 1, Farmer 2, Interview 1, Interview 2, Interview 4) (Fig. 1). The Bagrađa can be seen as a landscape actant: an external shock putting pressure within regime actors from the pest management regime, opening opportunities to the Integrated Pest Management and biological control niches, as we further elaborate below.

Among the first actants enrolled into the Bagrađa's network were affected conventional farmers who sought help to control the pest by connecting to three other regime actants: pesticides, the Municipality of Lampa, and an INIA extensionist (Farmer 1, Farmer 2, Interview 3, Interview 4, Interview 5). Surprised by the large number of Bagrađa in farmers' crops, the INIA extensionist reported the situation to a SAG regional officer (the SAG is the Ministry of Agriculture's Agency in charge of pest control and plants protection), who in turn, informed SAG's national authorities that the Bagrađa was becoming a serious problem. Farmers told us that at first, the SAG national authorities had a slow response (Farmer 1, Farmer 2). Whereas, a slow and bureaucratic response from the SAG was necessary in order to properly understand the pest (e.g. its behavior and biology) in order to create an adequate plan for its control (Interview 3).

One of the first measures of the resulting SAG action plan was testing and registering chemical pesticides to control the Bagrađa (Interview 3, Interview 4, SAG, 2017). Because the Bagrađa has been absent in Chile, when it started to spread there were no pesticides legally approved for its control (Interview 3). Under a situation of emergency –officially declared because of the great damage the Bagrađa was causing to farmers' crops– the SAG approved nineteen pesticides that had shown to be effective for controlling the Bagrađa (Interview 3, Interview 4; SAG, 2017). This action was collaboratively taken across three agencies associated with the Ministry of Agriculture: INIA (who tested the pesticides), SAG (who officially registered them), and FIA (who provided the funding) (Interview 3, Interview 4). This first measure corresponds to regime practices associated to pest management; so far, most farmers have depended on pesticides for managing the Bagrađa, and pests in general. And, it was seen as necessary to give farmers a fast and effective response, while stopping the Bagrađa from spreading to other territories, as both SAG and INIA officers indicated (Interview 3, Interview 4).

During the period that came after this list of 19 pesticides was approved, SAG inspector officers in the field noticed that farmers were applying too many chemicals in order to control the Bagrađa (Interview 3, Interview 4). Many farmers were fined by the SAG, and tensions among the SAG and farmers emerged due to the, at times, excessive or improper use of pesticides to control the Bagrađa (Farmer 1, Farmer 2, Interview 3, Interview 4).

Alternative methods to pesticides to help control the Bagrađa and reduce chemical applications were investigated by INIA researchers and extension officers with support of both SAG and FIA (Interview 3, Interview 4). In turn, three more actants were enrolled into the Bagrađa's network: i) entomo-pathogenic fungus, ii) insect's pheromones, and iii) plant-trap-corridors. These were being investigated and introduced by INIA and SAG officers in farmers' fields under the two-years project entitled 'Developing an Integrated Pest Management with low environmental impact for mitigating *Bagrađa hilaris*' populations for a competitive and sustainable horticulture'. This project was mandated by the SAG, funded by the FIA, and implemented by the INIA (Interview 3, Interview 4). As indicated by both a SAG and INIA officers, the objective of the project was not to eliminate farmers use of chemicals, but to make them transit to an integrated pest management (Interview 3, Interview 4).

Entomo-pathogenic fungi, which are fungi that attack insects, are effectively killing, and thus controlling, the Bagrađa. Additionally, pheromones have been shown to effectively attract the Bagrađa, and will allow farmers to remove pheromone-field-traps full of Chinchies and, in

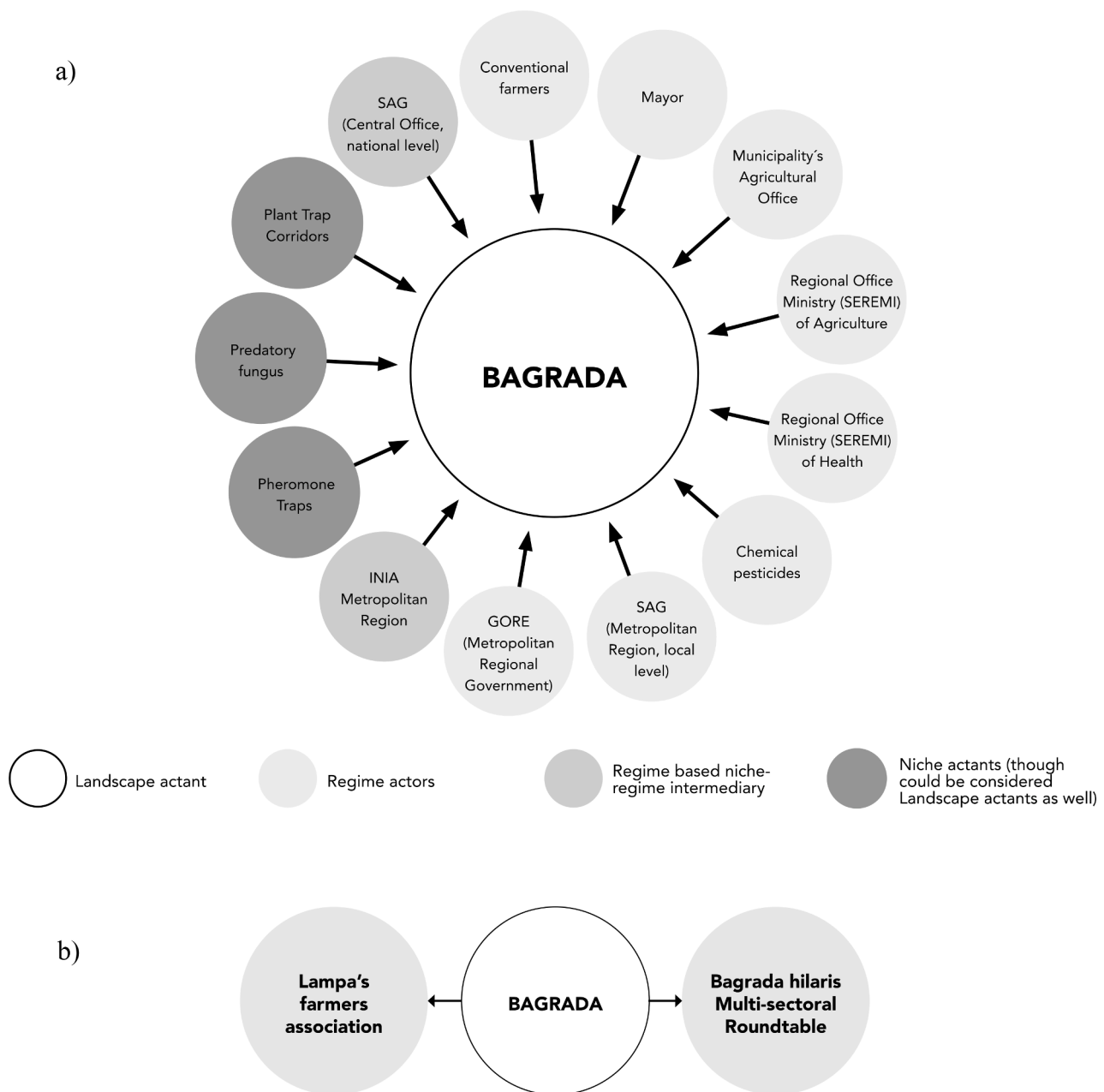


Fig. 1. Tracking the relations, actants and networks invoked by the Bagrada. 1.a) Actants –from different MLP levels– enrolled into the Bagrada's network. 1.b) New formal networks triggered by the Bagrada.

the case of plant-corridors, sprays to be targeting the corridor rather than the crop (Interview 3, Interview 4, Interview 6). The relations between the Bagrada and the three new network actants constitute promising alternatives to conventional pesticide use by helping to either reduce or replace chemical use, or at least to avoid chemical spreading over crops (Interview 3, Interview 4). Therefore, these fungus and plant-trap-corridors emerged as a focus for INIA researchers, who, through this two-year project implemented and tested these methods in both conventional and organic fields in Lampa. Entomo-pathogenic fungi, pheromones and plant-based corridors can be considered as actants from the niche, on which's relations to other actants the transitioning towards IPM and biological pest management methods depend.

We consider INIA, and partly the SAG, as 'hybrid actors': they belong to the regime level food system agencies (the Ministry of Agriculture), while also being the actors connecting and translating niche innovations (IPM, biological control) to the regime (Elzen et al., 2012). Further and

more precisely, we consider the INIA and SAG, as regime-based intermediaries (Fig. 1.a): they are part of the established institutions in the predominant socio-technical regime, but mandated or willing to work towards transformative change; as such, they also differentiate from non-transition-oriented regime intermediaries (Kivimaa et al., 2019a). As indicated by an INIA officer, *'the Bagrada will serve us as a tool, because it has been such an aggressive pest, leaving everyone surprised and the whole story, we will take it as an opportunity to persist with the issue of reducing and minimizing pesticides use'* (Interview 4). Hence, the Bagrada can be seen as both a catalyst and supporter of these regime-based intermediaries in their efforts to introduce IPM and, who in turn, are playing an important role in this transition-in-the-making, linking the need for IPM and biological control methods to the practices of regime conventional farmers.

As mentioned above, farmers also sought help from the Municipality of Lampa. There, the mayor advised farmers to organize themselves in order to have more strength in their demands to public agencies (Farmer

1). The advice and support of the mayor resulted in the creation of the first 'Asociación de Agricultores de Lampa' (Lampa's Farmers Association) in history, which now has 74 members, all of which are conventional farmers (regime actors) from Lampa. The formation of the 'Lampa's Farmers Association' was a relatively fast process taking around two months, during which Lampa's municipal social workers and lawyers were at farmers' disposal, in order to guide them in social and legal aspects related to what means to constitute and function as an organization (Farmer 1, Farmer 2). As a result of this work, farmers formed their association and voted to elect a President and Vice-President. The elected President and Vice-President were two farmers who had previously put together a list of names and signatures of all farmers from Lampa whose crops were being eaten by the *Bagrada*. While the aim of the list was to present it to public agencies in demand for support, it also helped as a first step to identify, convoke and organize farmers (Farmer 1, Farmer 2). Since then, both the President and Vice-President have been the spokespersons of the Association in the *Mesa-multisectorial de Bagrada hilaris de Lampa* (Farmer 1, Farmer 2, Mesa Observation).

The *Mesa-multisectorial de Bagrada hilaris de Lampa* (*Bagrada hilaris* Multi-sectoral Roundtable) is another network triggered by the damage brought about by the *Bagrada* (see Fig. 1.b). The Mesa was born out of the demand of the Lampa's Farmers Association –in their aim to receive support to tackle the *Bagrada*–, and convoked by Lampa's Agricultural Office (Interview 5). The Mesa is a multi-sectoral roundtable gathering together private actors (farmers) and public agencies from the local, regional and national level. Participants of the Mesa include: conventional farmers; Lampa's Municipality Agricultural Office; INIA La Platina (Metropolitan Region); the Regional Office of the Ministry of Agriculture (SEREMI de Agricultura); the Regional Office of the Ministry of Health (SEREMI de Salud); SAG officers from both the regional (field inspectors) and national levels (National Officer for protection against pests) (Interview 5, Mesa Observation). As indicated in an official Mesa's meeting-agenda, the aim of the Mesa is 'to create a space for communication, evaluation and developing coordinated strategies in order to face the problem *Bagrada hilaris* is causing in fields from Lampa and adjacent counties' (Mesa Observation, 05–06–2019).

In the Mesa, farmers and the different actors from the public sector local, regional, and national levels work together to find solutions for the *Bagrada* based on sustainable pest management methods (Mesa Observation). One of the Mesa actions has been the creation of a radio program broadcasted by Lampa's local radio. As an officer of Lampa's Agricultura Office mentioned, 'the radio program is aimed to improve farmers and public agencies relations, as farmers used to see [SAG] inspectors as enemies' (Interview 5). The latter, reflects the conflictual relations that at times have emerged, for example between SAG and Lampa's Farmers Association with regard to pest management as a response to excessive pesticide use.

As a result of the work done by the actors in the Mesa, the *Bagrada*'s pest management network has continued to expand. One of the latest Mesa achievements has been mobilizing a considerable amount of economic resources from the GORE (*Gobierno Regional* – Regional Government) in order to fight the *Bagrada*. The Mesa lobbied with COREs (*Consejeros Regionales* – Advisors from the Regional Government), who are elected representatives from the GORE, in order to secure funding for the pheromone-traps that have proven to be effective to attract and trap the *Bagrada* (Mesa Observation). Advised by COREs, the initial project of testing pheromone-traps turned into a more ambitious one: a project able to educate and reinforce in farmers the implementation of IPM practices (e.g. crop rotation, pest monitoring, applying the least pesticides possible, and in an informed and targeted manner), alongside with the other biological methods that were proving to be effective (Interview 3, Mesa Observation). Following CORE's advice, for a couple of months, in their meetings Mesa participants discussed what the project would look like (Mesa Observation), while this was co-written by INIA and SEREMI of Agriculture public officers (also Mesa participants), and continuously revised by the GORE for project improvements (Interview

3, Interview 4). Finally, the project was approved by the GORE.

In the Ministry of Agriculture Project, 'Developing an Integrated Pest Management with low environmental impact for mitigating *Bagrada hilaris*' populations for a competitive and sustainable horticulture', biological control agents have been researched by INIA officers as alternatives to chemical pesticides. The new project implies the transfer of both projects' findings to a total of 450 farmers in the Metropolitan Region, including management alternatives for the Chinche for conventional farmers, as well as organic farmers or those transitioning towards organic (Interview 4).

4.2. Roles of the *Bagrada* in the network

We can see the *Bagrada* provoking antagonistic relationships with all other actors in the Mesa, destabilizing an existing pest-management regime. Yet, we can see that the *Bagrada* catalyzes new elements being introduced, and new relationships forming within the pest management network so that vegetable production can continue. That is, as an antagonist, we see that the *Bagrada* has reorganized all other network actants (human and non-human), while also being an intermediary among these actants' relations, semiotically holding them together. For instance, while not physically present, the *Bagrada* is the central conceptual actant of the Mesa, as many Mesa participants indicated (Farmer 1, Farmer 2, Interview, 3, Interview 4, Interview 5, and Mesa Observation). As a farmer explained in a Mesa meeting 'if I am here is because of the Chinche' (Mesa Observation, 05–12–2018). With this we mean that the *Bagrada* is the actant maintaining the network, connecting previously disconnected regime actors, making them collaborate and coordinate their actions for a common objective: tackling the *Bagrada*.

We can also see how the *Bagrada* is producing changes in actants' roles and also in different human actants' (or actors) relations, as we will further explain here. In changing the roles of those actors, the *Bagrada* is requiring new actants to enter the network to stabilize its function. These may have broader regime and landscape changes in the overall system.

First, triggered by the *Bagrada*, while also supported by Lampa's mayor, we can see a change in conventional farmers' role in two senses. First, from uncoordinated and disparate actors within the territory to a legally constituted farmers' organization: the Lampa's Farmers Association. As an INIA officer indicated, 'the benefit of the Chinche is the organization that farmers have achieved among them, which is a tool they have from now on, that will help them in anything they aim to achieve' (Interview 4). The latter statement illustrates how regime changes may be emerging from the *Bagrada*. Indeed, while so far the work of both the Lampa's Farmers Organization and the Mesa have been focused on the battle against the *Bagrada*, the farmer's association –also through their work in the Mesa– has discussed how to approach and demand public agencies support for other agricultural issues, such as water scarcity, which every year appears more severe (Mesa Observation, 06–03–2019; Interview 5). Farmers value the organization they have achieved since the *Bagrada* arrived, signaling that they have realized how having an official organization is useful to them to achieve outcomes (Farmer 1, Farmers 2).

Second, as perceived by both farmers and an INIA officer, the *Bagrada* has been an opportunity to change the relationships among public officers and farmers (Farmer 1, Farmer 2, Interview 4). Since the Lampa's Farmers Association and the Mesa were created, farmers have taken an active role in the search of solutions for the Chinche, rather than being, as previously, subjects to which INIA researchers and extensionist 'transfer' research outcomes.

Third, the *Bagrada* and the work done in the Mesa has also produced changes among farmers' and SAG, as well as a change of role from the SAG. As a farmer would indicate:

'... the SAG came here and inspected us, saying that we were applying pesticides wrongly. But they assume that because you are a farmer you know all the legal, environmental and sanitary norms associated to

pesticides application. One of the effects of the Bagrada is our labor-union is unravelling and we don't have idea at all. That is why in the Mesa we demanded that they train us in legal, environmental and sanitary issues associated to pesticides use' (Farmer 2).

These tensions were exposed by farmers in the Mesa (Farmer 1, Farmer 2, Interview 3). As part of the solution, Mesa participants agreed on the implementation of training courses for farmers about the impacts of pesticides, as well as proper and safe use. So far, courses on 'maximum chemical-residues-allowed', 'credentials for chemical applicants', and 'Decreto 158' (a Ministry of Health legal norm concerning chemicals residues in vegetable), have been offered to farmers by public officers from the SAG, INIA and the Regional Office of the Ministry of Health, respectively. These courses, as well as a change of role of the SAG, are perceived by farmers as one of the Mesa's best achievements, along with the funding mobilized from the GORE project (Farmer 1, Farmer 2). As farmers indicated, they value a change of role in the SAG, which passed from being merely an inspector of pesticide use to also been a facilitator—in collaboration with the INIA—to farmers on the proper use of these chemicals (Farmer 1, Farmer 2). This change of role of the SAG has also helped to smooth farmers-SAG relations, which in turn have allowed them to better collaborate against the Bagrada, while slowly making farmers more aware and better informed about legal, health, safe and environmental issues related to pesticides use (Farmer 1, Farmer 2, Interview 3, Interview 4).

The Bagrada has been active in connecting previously disconnected regime actors, including farmers and public agencies, as well as public agencies that usually worked uncoordinated; such as the INIA and the SAG. Despite these two agencies belong to the Ministry of Agriculture, so far they have rarely worked together in addressing pest management issues (Interview 3, Interview 4). Also, by enrolling in the Mesa the SEREMI de Salud (Regional Office of the Ministry of Health), and its participation in giving training courses to farmers about pesticides damages and adequate use. In spite both the Ministry of Health and the Ministry of Agriculture have a role in safeguarding adequate pesticides use (e.g. inspecting, testing pesticides) both Ministries also use to work uncoordinatedly, independent from each other (Interview 3, Interview 4). As indicated by a Mesa member, *'if we can attribute something to the Chinche is that it has helped farmers and public agencies to collaborate, and to realize that working together we can achieve better outcomes'* (Interview 4).

The Bagrada is also producing changes in the relations farmers have to pesticides, requiring new forms of knowledge and institutional support, as well as in the role pesticides play within the network, requiring the introduction of new pest management strategies. While there are also efforts to change farmers' use of pesticides in vegetable production through legal and social means, to some extent, the changes we describe have been compelled directly by the Bagrada and its effects on the very functioning of pesticides. That is, changes in the relation of farmers towards pesticides are not solely due to both the inspecting and educating role of the SAG (which in turn, derived from the excessive use farmers were doing to control the Bagrada). If it were up to many of these farmers, they would continue to apply as much pesticides as they can (Interview 3, Interview 4). However, the Bagrada is such an aggressive pest that it would demand excessive chemical applications for an effective control, which ultimately is not economically viable for farmers (Farmer 1, Farmer 2, Interview 3, Interview 4). The problem of the Bagrada is its high mating rates; thus, while pesticides can kill adult Chinchies, they don't destroy the huge amount of eggs present in the soil, which then hatch, leading to crops full of Chinchies again, as explained by an INIA officer.

The lack of an effective response of the Bagrada to pesticides is compelling farmers to realize for the first time, that pesticides will not be an effective nor economical solution to tackle the Bagrada, challenging previous reliance on pesticides. Farmers have come to see that: *'the solution [for controlling the Bagrada] will be to research and see which are*

going to be the best fungus [for a biological control of Bagrada], because it was already proven that chemicals did not gave results and that biological control is the ideal...Chemicals are not solution because on the one side, it is not business [as an effective chemical control for Bagrada demands too much applications], but also because they harm people's health' (Farmer 1).

In other words, we can see that the Bagrada changes the function of chemical pesticides, by translating them from an easy pest control to one that is expensive and unreliable. This is compounded by the network effects of public concern, regulation, and audits, which also help to reframe chemical pesticides as dangerous and undesirable. Without anything to combat the Bagrada, the pest management network is unstable, and requires the introduction of new actants to keep the Bagrada in check. Therefore, while the Bagrada is changing farmers' relations to pesticides, as they do not appear effective anymore, niche biological control actants—such as entomo-pathogenic fungus—are starting to be more appealing for farmers, gaining a particularly meaningful role in the network and enabling changes to dominant relations between farmers and pesticides, characterized by farmers' strong dependence on chemicals as the primary and only means of pest control.

5. Discussion

In this paper we address the role of non-human agency in sustainability transitions specifically asking what is the role of a non-human actant, the agricultural pest *Bagrada hilaris*, drawing on a case of a transition-in-the-making towards integrated pest management, and less and more responsible chemical use in agriculture.

Here we reflect on our main findings, particularly with regard to three main elements. First, the actions and roles of non-human agency in sustainability transitions. Second, the relational nature of agency. And third, the implications of our findings for the MLP theory, particularly, in regard to how actants from the three MLP levels may interact.

5.1. Non-human agency in transitions: supportive and antagonistic actions and roles that condition human agency

By tracing the emergent networks surrounding the *Bagrada hilaris*, we have illustrated how non-human actants play a role in sustainable food systems transitions through the actions of destabilizing regime practices and framings associated with pesticides use, creating and intermediating relationships, changing the roles of other human and non-human actants and disrupting their networks, and compelling new actants to join the pest management network. One of the reasons the Bagrada was effective at catalyzing transitions was that it has multiple network effects: it creates or illuminates the shortcomings of pesticides, the need for new organization and knowledge networks, the value of entomo-pathogenic fungi, traps and corridor techniques—that create a world in which the IPM niche is rational and practically necessary. These multiple network effects, together, can be seen to amount to a broader regime change that includes shifts in institutional organization, cultural norms and practices.

Some of the agentic actions and roles played by the Bagrada are in line with those identified in previous studies about agency in transitions. These included connecting previously disperse (human) actors (Fischer and Newig, 2016; Kivimaa et al., 2019a, 2019b) from the regime, triggering the creation of alliances and networking (Musiolik et al., 2012; Kivimaa et al., 2019a, 2019b; Westley et al., 2013), and in that sense also acting as a 'boundary object' (Franco-Torres et al., 2020; Tisenkopfs et al., 2015). Further, we see the Bagrada playing simultaneously different roles in relation to other actants. While being an antagonist to all other actants from its network, the Bagrada has also performed the roles of a catalyst for the need of transition towards IPM, and of other actants' agency as well; thus, being a connector (de Haan and Rotmans, 2018), triggering the development of two new formal networks of actors committed to defeating it; an intermediary or facilitator of these

networks of both material and semiotic relations; and a supporter (de Haan and Rotmans, 2018) of other actants' agency –in our case, of human niche-regime based intermediaries that have been striving to push on IPM and reduce chemical use in Chilean agriculture. Yet, the supporter role performed by the Bagrada differs from the one defined by de Haan & Rotmans (2018), who define (human) supporters as actors that are not transformative themselves, but whose endorsement provides legitimization by expressing the societal need for changed systems (de Haan and Rotmans, 2018). In contrast, also as a supporter the Bagrada is a transformative agent, which emerges in several ways from the findings.

We see the Bagrada as a transformer in that it has transformed other actants roles and practices and, in doing so, it has also changed the relations between actants, both human and non-human. The Bagrada has induced or mediated changes in the roles of the SAG, pesticides, and biological control agents (e.g. pheromone traps and entomo-pathogenic fungi), among other examples depicted in the findings section. At first the SAG was limited to being an inspector of farmers' chemicals use –which generated tensions among SAG and farmers–, to thereafter also adopting the role of a facilitator –together with the Ministry of Health, the INIA, and the Municipality– for farmers on relevant information and knowledge on why and how to make a responsible pesticide use. This change of role in the SAG helped to smooth conflictual relations between the SAG and farmers. With regards to pesticides, at the beginning these were the most efficient technology to tackle the Bagrada –for both farmers and public agencies–, to later on being conceived by public agencies as dangerous artefacts which's application must be reduced, while inefficient and uneconomic technologies to combat the Bagrada for farmers. Whereas, predatory fungi went from being unknown or disregarded by farmers, to being an auspicious solution to control the Bagrada for them and public agencies. These examples illustrate how fundamental changes in actants roles and in their relations are for advancing a transition process.

These findings have several theoretical implications for understanding (non-human) agency in sustainability transitions. First, as indicated above, the Bagrada's capacity of changing actants roles and their relations, constitutes a significant role in advancing this transition-in-the-making. This is in line with Wittmayer et al. (2017) indication that fundamental changes in the roles of (human) actors and their (changing) relation to other roles are a vital element of any sustainability transition. Also ANT translation phases of enrolment and inter-essement emphasize the importance of actions that attempt to constantly (re)work on other actants' roles and relations in order to create, maintain and expand the network. Therefore, reinforcing Wittmayer et al., 2017, we consider that the capacity of changing actants roles –by creating new roles, breaking down or altering existing ones (Wittmayer et al., 2017)–, should be consider as a relevant agentic role within studies and frameworks about agency in transition, and also addressed as part of the set of actions of 'institutional work'.

Second, the fact that the Bagrada simultaneously plays different agency roles –while at the same time being an antagonist to all other actants from its network– coincides with previous studies indicating that (human) actors' roles in transitions are erratic, as actors can belong to different (role) categories that change over time and phase of the transition (Fischer and Newig, 2016). Furthermore, in our case the Bagrada was not only an antagonist to all other actants from its network, but also triggered paradoxical actions. On the one hand, producing an excessive application of pesticides, while, on the other hand, catalyzing and inducing different actions and network effects supporting the feasibility of the IPM niche. These findings challenge binary notions of actors as either opponents or supporters of transitions, which has been noted earlier (Geels et al., 2016). Research on agency in transitions should not focus on the expected roles to be performed by different types of actors (e.g. opponents and supporters; government are incumbents, or opponents to transitions) as conducted in previous research (Farla et al., 2012), but instead, following Wittmayer et al., 2017, on the multiple and

diverse roles –socially constructed, negotiated and open to change– different types of actors (as well as non-human actants) may simultaneously play (Wittmayer et al., 2017); something that can be further studied.

Third, the fact that some of the agentic actions and roles played by the Bagrada have also been identified in previous studies about human agency in transitions does not mean that non-human and human agency are equal, as previous authors also signal (Latour, 2005; Sayes, 2014; Svensson and Nikoleris, 2018). Nonetheless, it does show that there are relevant actions and roles for advancing sustainability transitions that both humans and non-humans may do and portray. Furthermore, in line with previous authors, we do not attribute to the Bagrada, and other non-humans as well, material determinism (Latour, 2005; Legun and Henry, 2017; Müller and Schurr, 2016; Svensson and Nikoleris, 2018). The Bagrada does not determine human agency, but as we have shown in our findings, it has the capacity to condition other actors' agencies; limiting, enabling or supporting their possible actions. Hence, it is important to start taking into consideration non-human agency within sustainability transition frameworks and research as others have also noted recently (Kok et al., 2021; Pigford et al., 2018).

5.2. Agency as relational, constructed and dependent on different actants interactions

Previous transition studies on strategic agency to support regime change have shown and emphasize how agency is relational and constituted by the interactions and dependences among different actors (Werbeloff et al., 2016). The relational, network effects of our non-human subject, the Bagrada, is clear. In our case we can see that a transition to less and responsible pesticide use and more biologically-based pest-management strategies had been attempted previously by regime-based actors as the INIA, and efforts were underway to convince farmers to switch onto these alternative practices. Alone, these discussions were unlikely to lead to significant practical change in the short-term. Moreover, despite these regime-based intermediaries intentions and normative ideals for IPM, what finally triggered this particular transition-in-the-making were the conflicts that arose among farmers and policy officers due to heavy pesticide use because of the Bagrada excessively eating crops, as well as farmers' economic (rather than normative) motivations for adopting IPM in order to reduce their expenditures in pesticides. These findings illustrate that we should not limit our understanding of agency in transitions to human agency through intentional, rational and strategic actions, as has so far been the focus of most transition and transformation studies about agency (Brown et al., 2013; Farla et al., 2012; Geels, 2020; Werbeloff et al., 2016; Westley et al., 2013). While intentional human action is a type of action, it is not the only type of action nor is incompatible with other forms of agency (Sayes, 2014). In line with previous studies (Legun, 2015; Rosin et al., 2017), we contend that regardless of how intentional and/or strategic human agency is, at the end, agency is conditioned (limited or enhanced) and dependent on the interactions with both other non-humans and humans (Legun, 2015; Legun and Henry, 2017; Rosin et al., 2017; Sayes, 2014; Shin, 2019).

These findings reinforce previous studies that caution against too much emphasis on sustainability transitions as consensual or deliberative processes that can be intentionally managed into a certain normative direction (Avelino, 2009; Hargreaves et al., 2013; Meadowcroft, 2009; Rossi et al., 2019; Shove and Walker, 2007). We agree with other authors that such an understanding of transitions may neglect interactions of conflict or (political) struggles among the involved actors, which not only seem unavoidable but also relevant in the transition-in-the-making (Avelino and Wittmayer, 2016; Geels, 2020; Genus and Coles, 2008; Jolly and Raven, 2015; Jørgensen, 2012; Meadowcroft, 2009), or overlook the role of contingency, unpredictability and untidiness in transitions: something that flat ontology approaches –including ANT– can contribute to transition studies (Geels,

2011).

Nonetheless, the existence of (previous) regime-based actors efforts influenced the significant effects that the Bagrada had on pest-management, as the tools and discourses of IPM and biological controls were readily available and pushed by the INIA, mainly. Likewise, we could see chemical regulations and SAG as influencing the effects of the Bagrada, as together they shaped the development of new training courses on chemicals and residues. We can also see how their actions for creating farmers' awareness about an informed and responsible pesticides use, and encouraging them to adopt IPM and biological control methods, are supported and dependent on non-human actants; including the Bagrada, entomo-pathogenic fungus, plant-based corridors. Further, the pathogenic nature of the relationship between the Bagrada and an entomo-pathogenic fungus has led to an expansion of research and a promising pathway forward for biological controls. While we focus on the Bagrada as a non-human actant, it is not a bounded, solitary actant, but the agency it has is very much defined by its network relations.

This serves to emphasize the ways that an actant is, in part, defined by other humans and non-humans' capacity and likely to be changed by them. As such, our findings underpin previous transition studies emphasizing agency as relational and constituted by the interactions and dependences among different actors (Werbeloff et al., 2016; Rossi et al., 2019); including both humans and non-humans (Rosin et al., 2017). Our findings also are in line with those studies drawing from institutional theory concepts such as institutional work and collective-institutional entrepreneurship that refrain from notions of heroic change agents that are able to bring-up systemic change on their own (Jolly, 2016). Therefore, we recognize the possible need to go beyond transformative agency frameworks that explain transformative change as the outcome of particular strategies played by transformative actors (Westley et al., 2011), or, as the consequence of the intentional actions of different typological actor roles, that is, ideal types of transformative change agents with different strategies and abilities (de Haan and Rotmans, 2018). In turn, we have shown how research about agency in transitions can benefit from theoretical approaches that allow us to capture the relational and interactional dynamics among multiple and diverse actants –human and non-human– involved in transition processes. For instance, following the work of Kivimaa et al. (2019b) who use an 'ecology of intermediaries' perspective (or, as in our case, an 'ecology of actants'). Such a perspective emphasizes that, while some type of intermediaries (e.g. niche, systemic) are the most important for transitions, these need be complemented by a full ecology of intermediaries; including regime based intermediaries (Kivimaa et al., 2019b). Or, in line with the authors of previous transition studies, through the application of relational approaches such as ANT (Geels, 2010; Genus and Coles, 2008; Garud and Gehman, 2012; Diaz et al., 2013) or assemblages (DeLanda, 2016; Legun and Henry, 2017). These approaches conceive agency as a result from the relations of heterogeneous entities, both human and non-human (Müller and Schurr, 2016). As such, they can help us not only to address non-human agency, but also to examine the interdependences and interactions among diverse human and non-human actants.

In view of our findings, we argue that complementing the MLP with ANT can help us to understand the interactions among the actants across different levels involved in a transition process, and how their agencies relate to each other.

5.3. Implications of non-human agency for the MLP: actants' interactions at different MLP levels

Our analysis and findings have two theoretical implications for the MLP as an heuristic to understand and structure transitions.

First, the case of the Bagrada shows how a whole network of both human and non-human actants distributed across the three MLP levels (and intermediate spaces between levels) are involved in the transition-in-the-making process. These findings support Jørgensen (2012) who

argues that agency for transitions is not necessarily confined to any particular level, while (human) actors engaged at all levels are not working in isolation. Our findings also concede with previous studies indicating that distinctive boundaries between niche and regime become less clear empirically as the MLP implies (Smith et al., 2010), and that niche boundaries are not so clear cut but fluid, continuously (de)enrolling new actors (also from the regime) and redefining the links that hold the network together (Jørgensen, 2012; Diaz et al., 2013). In the case of the Bagrada we see this in the difficulty associated with categorizing biological pest agents as niche or landscape actants, as well as in the important role for advancing the IPM niche played by the INIA and SAG regime-based intermediaries, and the fact that the network of actants supporting the IPM niche belong to the landscape, regime, and regime-niche intermediate levels, rather than to the niche level. This reinforces previous studies that, through a crossing-over between MLP and ANT, have unraveled the fluidity of niches (Diaz et al., 2013).

Second, supporting previous studies (Antadze and McGowan, 2017; Avelino et al., 2017; Svensson and Nikoleris, 2018; Weng et al., 2020), the landscape no longer appears as a level without agency, void of actors (or actants) performing functions that help to advance transitions (Fischer and Newig, 2016), nor as a level in which its material aspects lack autonomous causal efficacy (Svensson and Nikoleris, 2018). As indicated by Kivimaa et al. (2019b), there is a lack of studies on regime-landscape and landscape-level intermediation. We have shown how non-human actants at the landscape level are relevant change agents, and argue that this deserve further attention. Our findings demonstrate how a landscape non-human actant –the Bagrada– is an actant causing, supporting, and reinforcing the transition from heavy chemical use to other more sustainable methods. The usefulness of distinct levels for the understanding and categorization of change agents, and actors in general, has already been questioned by previous studies (El Bilali, 2019; Elzen et al., 2012; Jørgensen, 2012; Shove and Walker, 2010; Smith et al., 2010). Analytically, actors (and actants) cannot be attached only to one level, for example, niche-actors, regime-actors; empirically, actors are involved in transforming and intervening at all levels, without necessarily the MLP explicit about distinguishing between them (Jørgensen, 2012).

6. Conclusion: theoretical and practical recommendations for transition studies

While agency in transitions has received considerable attention lately in transition studies, this is focused on agency of humans. Non-humans within transition studies –such as infrastructures or the natural environment– have been recognized as relevant factors influencing sustainability transitions. However, they have not been adequately considered as agents in transition studies. By answering the question '*what is the role of the non-human actor Bagrada hilaris in shaping the transition-in-the-making towards more sustainable food systems in Chile?*' we have shown that non-humans can be relevant change agents in provoking and catalyzing a process of transition, simultaneously doing and performing varied agentic actions and roles that disrupt the regime and reinforce a transition process, while also conditioning human agency: limiting, enabling or supporting humans possible actions. Therefore, we conclude that non-humans can be an important foundation influencing human agency and overall social change for transitions.

6.1. Theoretical and methodological recommendations for future research

For reasons outlined above, including non-human agency alongside human agency deserves further consideration in transition studies. Furthermore, research on agency in transitions should not be limited to strategic intentional human action, nor focused on the expected roles to be performed by different types of human or non-human actants, but on the relational and interactional dynamics among multiple and diverse agents –human and non-human– involved in transition processes

(echoing Darnhofer, 2020; West et al., 2020). The agency of non-human and/or human actants, or their capacity for making transformative change happen, seems very much defined by their network relations, while likely to be changed by them. Our study indicates that actions related to changing actants roles and their relations, play a significant role in advancing this transition-in-the-making. Therefore, with regard to the MLP as an heuristic to understand and structure transitions our study has two main theoretical implications. First, that a whole network of both human and non-human actants distributed across the three MLP levels (and intermediate spaces between levels) are involved in the transition process. Secondly, that considering non-human agency implies that the landscape is no longer a level where there is no agency.

As a methodological recommendation, in line with previous studies (Diaz et al., 2013; Svensson and Nikoleris, 2018), the cross-over between the MLP and ANT proved fruitful for our research. The MLP allowed us to place actants at three different levels, helping us to unravel that diverse human and non-human actants from these levels are involved in a transition. ANT allowed us to trace and analyze the actions and relations of each actant within emerging networks of relations, which further allowed us to understand actants interactions across all MLP levels. Given this, research about agency in transition may benefit from cross-overs with ANT or other relational approaches such as assemblages approaches (Darnhofer, 2020; Legun and Henry, 2017; Shim and Shin, 2019; West et al., 2020), that allow to address non-human agency, as well as agency as a composite involving both humans' and non-humans' action (Kok et al., 2021).

Finally, we are aware that our conclusions are derived from a single case study. A study such as ours could be repeated in other places and at other scales, to further examine varied forms of non-human agency in transition studies. Moreover, while our findings showed the positive effects of a non-human actant in catalyzing a transition, being cognizant of power dynamics in relational approaches (Kok et al., 2021), further research should examine the ways in which non-humans might block sustainability transitions and, in general, the multiple and varied ways in which humans and non-humans interactions help to either advance and hinder sustainability transitions.

6.2. Reflections for transition practice

A number of reflections for transition practice have emerged from our analysis. A first reflection for those willing to steer processes of sustainability transitions is the importance of identifying changes in actants roles and in the relations between actants needed for advancing sustainability transitions through a mapping approach such as the one applied in this paper.

Secondly, considering the specific context of every transition and socio-technical system (Shin, 2019), for any particular transition process transition practitioners need to recognize the multiplicity and diversity of agencies involved. They need to make sure these diverse agencies are addressed in ways that allow for both the identification of and for coping with the limitations of our human agency, and facilitate the interdependencies between the different agencies involved in a particular transition process. This would imply, following recent work of West et al. (2020), the importance of bringing relational ontologies into transdisciplinary research processes and sustainability interventions.

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